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64th Congress
2d Session

HOUSE OF REPRESENTATIVES

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No. 2137

DEPARTMENT OF COMMERCE

BULLETIN
OF THE
UNITED STATES BUREAU OF FISHERIES

VOL. XXXVI
1917-1918

HUGH M. SMITH
COMMISSIONER

Smithsonian Institution
AUG 10 1921
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National Museum

WASHINGTON
GOVERNMENT PRINTING OFFICE
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THREE NEW WHITEFISHES FROM BEAR LAKE, IDAHO AND UTAH

By John Otterbein Snyder

THREE NEW WHITEFISHES FROM BEAR LAKE, IDAHO AND UTAH.

By JOHN OTTERBEIN SNYDER.

INTRODUCTION.

It is the purpose of this paper to direct attention to some little known but very important food fishes in Bear Lake, Idaho and Utah. Aside from their value as food, these fishes are of interest to ichthyologists, as they belong to previously unknown forms that have managed to survive as representatives of an ancient quaternary fauna, which was no doubt composed of numerous species of relatively wide distribution. At present they are confined to a single small lake, and they therefore remind us of the animals of certain oceanic islands which have been preserved under favorable conditions, while others of their kind less favored have long since passed away.

Bear Lake is a part of the drainage system of Great Salt Lake, the connection being through Bear River, which has its origin among the mountains of the eastern slopes of the Wasatch Ranges. Through the channel of its outlet, Bear Lake was at one time connected with the quaternary Lake Bonneville, the shore lines of which are still plainly traced along the sides of the bordering mountains. The outlet of Lake Bonneville carried its overflow into Snake River, and thus Bear Lake was for a time a part of the Columbia River system.

In the course of an investigation of the food fishes of the Great Salt Lake system, under the authority of the United States Bureau of Fisheries, the writer was attracted to Bear Lake principally because deep-water fishes were reported there. The lake, roughly estimated, measures about 9 by 25 miles in extent. It is deep and clear, the limpid water, always rich in reflected colors, reminding one of Lake Tahoe, although Bear Lake lacks to a degree the wonderful setting of mountains characteristic of the latter. Bear Lake and Bear River were found to contain most of the fishes indigenous to the Great Salt Lake system, and in addition three whitefishes of species heretofore undescribed. One of these belongs to *Leucichthys*, a genus not previously known to be represented in the West. This is a small fish, measuring about 7½ inches when mature. The others are species of *Coregonus*, which is represented also by *C. williamsoni*, a common fish of the streams. Of these, *Coregonus spilonotus* grows to large size, while the other, commonly known as the herring, is much smaller. They are excellent food fishes, and have long been known to ranchers near the lake, where they are taken in considerable numbers. Because of the limited supply, these fishes contribute to the local demand only. The writer has reason to believe, however, that they are of relatively great potential value, especially in the West, where there are many deep alpine lakes. These lakes are not known to contain similar fishes, and it is probable that the best of these might be introduced without seriously disturbing the native species.[a] As the introduction of eastern whitefish has been attempted in western lakes without success, it is worth considering that we have here one or more deep-water species which may prove to be better adapted. Two of the species here described are said to live and spawn in deep water, while the other species spawns near shore and returns to the depths immediately afterwards.[a] They are therefore only indirectly dependent upon the shore fauna of the lake, and they never enter the streams. In life they are all light green on the dorsal surface, silvery on the sides, and white beneath. Associated with them in deep water, and similarly colored, are large individuals of the trout, *Salmo utah*.[b] The sculpin, *Cottus semiscaber*, was also caught at the same depth. Examples of the latter were covered with prickles. They were pale ash gray in color, like the bottom, specimens of which adhered to the line anchors.

---

[a] Nothing is known of the habits, distribution, or abundance of Bear Lake whitefishes except that which is now recorded. Their life history should be carefully investigated before an attempt is made to introduce them elsewhere, and their artificial distribution should be preceded by experimental work to safeguard the possibility that their presence in a new locality may be detrimental to valuable native species.

The immediate relationships of these whitefishes are not evident. Nothing like them occurs within the present confines of the Bonneville system, nor in the Columbia, which was its former outlet. In fact they appear to be widely separated from any possible allies, unless the latter remain to be discovered in the depths of other western mountain lakes of high altitude. It is quite probable that at some time, possibly during the high-water stage of Lake Bonneville, these species were much more widely distributed than at present. They were probably numerous in Lake Bonneville, and their range may have extended to other mountain lakes of the Columbia system, and even to Lake Lahontan and the quaternary lakes of eastern Oregon. If such were indeed the case, it is remarkable that they should not have been preserved in Lakes Chelan, Kaniksu, Tahoe, and others of similar character. The deep waters of these lakes have not been explored, and it is not altogether unreasonable to suspect that similiar fishes may now be found there.[c]

Descriptions of the species and brief notes on their habits follow:

SYSTEMATIC DISCUSSION OF SPECIES.

Leucichthys gemmifer, new species. Bonneville cisco.

The Bonneville cisco is taken during the winter in large numbers. It is caught in gill nets set through the ice. It may also be taken in the summer, when it is not so numerously represented on the bottom. Large schools may then be seen near the surface. It is at no time found near shore.

Although of small size, it is an excellent food fish. It is largely used by the local fishermen as bait, and when so employed it seems to be selected in preference to other fish by both the larger whitefish and the trout.

This species, locally known as "peak-nose" because of its pointed snout, measures about 7½ inches when mature. It is pale moss-green above, with silvery sides which have a pearly iridescence. The under parts are white. The tip of the snout is pale pink, and a few scales on the base of the caudal are strongly tinged with purple.

Spawning occurs in deep water during the latter half of January. Examples of both males and females collected at that time by Mr. Stock have conspicuous pearly nodules on all the scales from head to tail except those of the ventral surface. These nodules are conical in shape, sharply pointed, and larger in the region of the lateral line. No trace of the nodules appears in summer specimens, when the mucous coating of the scales is rather thin, and the surface is bright and smooth. Similar nuptial ornaments have not been reported as occurring on other species of the genus.

---

[a] Many specimens of two species were collected during the spawning period by J. P. Stock, of Fish Haven, Idaho. Notes on the habits of the fishes were also contributed by him.

The drawings are by W. S. Atkinson.

[b] Through some oversight the name *Salmo virginalis* has been wrongly applied to the trout of the Salt Lake basin, which should be called *Salmo utah*, the name given it by Suckley. *Salmo virginalis* is the trout of the Rio Grande.

[c] *Coregonus coulteri* Eigenmann was described from young examples of the species. Individuals of the year were collected also in Diamond Lake, Wash., where they may, perhaps, reach a large size.

An examination of a few stomachs revealed nothing.

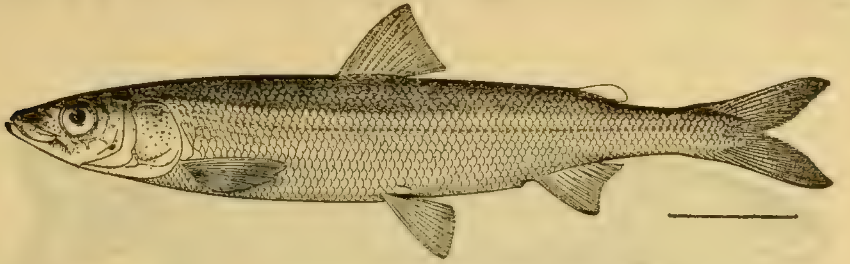
Forty specimens show a range in size from 162 to 180 millimeters in total length, and, unless the scale markings are wrongly interpreted, the ages of these examples are 4 and 5 years.

The species differs from others of the genus in the possession of a slender head with a long, sharply pointed snout, and a narrow maxillary which is entirely in front of the eye. The cisco does not resemble any other whitefish of the basin, and it will not be confused with any of them by the casual observer.

Type No. 83498, United States National Museum. Locality, Bear Lake, near Fish Haven, Idaho. Length 173 millimeters. Collectors, J. O. Snyder and C. L. Hubbs.

Head 4.4 in length to base of caudal; depth 5.6; depth caudal peduncle 3.8 in head; snout 3.2; eye 4.5; interorbital area 4.5; maxillary 3.4; scales lateral series 71; between occiput and dorsal 29; above lateral line 8; below lateral line 7; dorsal rays 11; anal rays 12.

Body elongate and slender, the head pointed; eye large; maxillary entirely in front of eye; no teeth; gill rakers long and slender, 14 to 27 on first arch; cæca 85; fins short, caudal lobe pointed, adipose small. Color dusky above, silvery on the sides; no spots.



Leucichthys gemmifer. Bonneville cisco.

MEASUREMENTS OF TEN EXAMPLES OF LEUCICHTHYS GEMMIFER.

Length of body.................mm..	149	157	157	149	141	141	155	143	146	142
	♂	♂	♂	♂	♂	♀	♀	♀	♀	♀
Length head	0.245	0.24	0.24	0.24	0.25	0.25	0.25	0.25	0.24	0.25
Depth body	.21	.19	.195	.195	.215	.24	.25	.23	.23	.225
Depth caudal peduncle	.07	.067	.07	.065	.07	.07	.065	.065	.07	.06
Length caudal peduncle	.155	.15	.16	.165	.165	.15	.16	.155	.155	.165
Length snout	.07	.075	.07	.075	.09	.08	.075	.075	.075	.085
Length maxillary	.065	.075	.075	.07	.078	.075	.075	.07	.072	.075
Diameter eye	.053	.055	.05	.055	.058	.055	.055	.057	.052	.05
Interorbital width	.053	.053	.055	.055	.055	.055	.05	.053	.055	.055
Depth head	.13	.13	.13	.14	.14	.14	.14	.14	.14	.14
Snout to occiput	.175	.175	.18	.175	.20	.185	.185	.19	.18	.185
Snout to dorsal	.48	.50	.48	.47	.51	.48	.49	.49	.47	.48
Snout to ventral	.55	.58	.54	.56	.56	.555	.575	.55	.555	.555
Length base of dorsal	.10	.095	.095	.09	.092	.11	.09	.10	.105	.10
Length base of anal	.095	.095	.09	.10	.095	.10	.09	.095	.10	.095
Height dorsal	.125	.12	.125	.12	.125	.13	.125	.115	.12	.12
Height anal	.095	.095	.09	.09	.09	.10	.095	.09	.09	.10
Length pectoral	.16	.145	.155	.145	.16	.15	.15	.14	.15	.15
Length ventral	.12	.115	.12	.115	.12	.115	.12	.115	.115	.115
Length caudal	.20	.19	.175	.19	.20	.20	.20	.18	.20	.20
Dorsal rays	10	11	11	11	9	11	11	11	11	11
Anal rays	11	11	11	12	12	12	11	11	12	12
Scales lateral line	77	73	71	71	72	72	73	73	74	72
Scales above lateral line	8	8	9	9	8	8	8	8	8	8
Scales below lateral line	7	7	7	7	7	7	7	7	7	7
Scales before dorsal	30	31	32	31	29	29	30	30	31	29

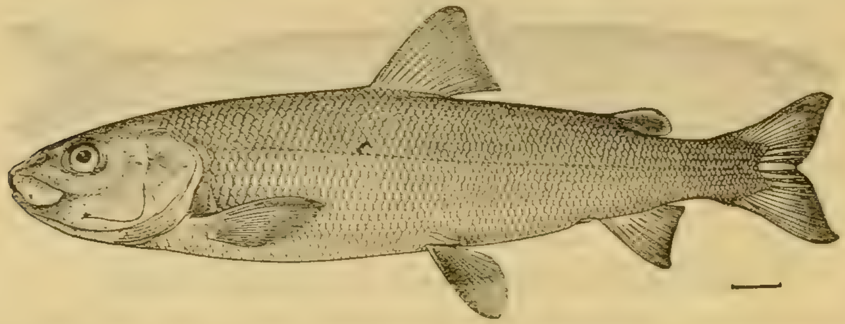
The color soon fades after death. An alcoholic specimen is brown to a point two scales above the lateral line, from where it is silvery to the midventral surface. Along the back the scales are dusky. The snout is black on the upper anterior half. The fins are without color.

The intestinal canal is short and straight. There are 84 to 86 cæca just beyond the pyloris, the posterior 10 or 12 extending in a single row along the intestine. The gill rakers are longest near the center of the arch, about one-half the length of the maxillary. They number 14 to 16+27 or 28. Branchiostegals 8. The air bladder is large, thin, and single lobed, extending the whole length of the visceral cavity. The peritoneum is somewhat silvery in places, but is without dark pigment. No teeth are found.

Coregonus spilonotus, new species. Bonneville whitefish.

Gill nets set at a depth of about a hundred feet in Bear Lake in August caught numbers of a spotted whitefish which measured from 155 to 200 millimeters in length. They were pale moss-green above, silvery on the sides, and white beneath. Spots, dusky in color, round, and somewhat larger than the pupil, extend from the occiput to the base of the caudal. These fishes differ from *C. williamsoni* in that the spots are smaller and more numerous, the scales are larger, and the heads longer. They were from 4 to 5 years old, and the condition of the ovaries seems to indicate that they were mature individuals.

At the same time and at the same depth large whitefish colored like the above, except that they were without spots, were taken on baited hooks. Besides being plain in color, these fish were much larger, 400 to 470 millimeters long; the heads were longer, the body deeper, the maxillary larger, and they were distinguished also by their general appearance. They were from 7 to 10 years old, and mature.



Coregonus spilonotus. Bonneville whitefish.

Locally these two forms are regarded as distinct, but a considerable series of specimens collected by Mr. Stock supplies examples intermediate in size and age, and seems to demonstrate without much doubt that they belong to the same species. The question need not be considered as settled, however, until more complete data have been obtained.

This species appears to inhabit the deep water. It is to be found there as late as the month of August, and it is in the same region in January and February, when it feeds upon the eggs of other whitefish. In December, however, it migrates shoreward and spawns in shallow water. It does not enter the rivers.

Type No. 83499, United States National Museum. Locality, Bear Lake, near Fish Haven, Idaho. Length 425 millimeters. Collectors, J. O. Snyder and C. L. Hubbs.

Head 3.8 in length to base of caudal; depth 3.6; depth caudal peduncle 3.5 in head; snout 2.9; eye 4.8; interorbital area 3; maxillary 3.2; scales lateral series 80; between occiput and dorsal 34; above lateral line 11; below lateral line 9; dorsal rays 11; anal 11.

Body deep and rather heavy, the head very large, with a long snout and broad maxillary. Gill rakers short, thick, and pointed, 6+13 on first arch. Fins rounded; caudal small; adipose about equal in size to maxillary. Color dusky above, silvery on the sides, white below; no spots.

The spots disappear with age, the head grows relatively larger, the maxillary longer, and the body deeper. The lateral series of scales numbers from 74 to 81; series above lateral line 9 to 11; between occiput and dorsal fin 30 to 37. The dorsal has 10 to 12 rays; anal 9 to 11.

Measurements of Coregonus spilonotus.

	No spots; size large.							Spots subdued; size medium.					Spots very distinct; size small.									
Length of body............mm..	365	322	408	390	405	374	375	214	200	212	208	202	153	158	175	170	160	153	162	156	150	132
Length head	0.245	0.275	0.27	0.26	0.255	0.265	0.255	0.253	0.25	0.25	0.255	0.25	0.22	0.225	0.23	0.215	0.22	0.22	0.23	0.22	0.23	0.23
Depth body	.25	.235	.215	.24	.28	.24	.26	.25	.22	.25	.23	.22	.23	.225	.23	.22	.21	.22	.23	.23	.23	.215
Depth caudal peduncle	.07	.075	.07	.08	.075	.075	.075	.075	.075	.075	.075	.072	.075	.08	.08	.075	.07	.07	.075	.07	.08	.07
Length snout	.075	.083	.086	.09	.083	.09	.09	.085	.075	.075	.08	.08	.07	.075	.065	.06	.065	.06	.065	.062	.057	.06
Length maxillary	.075	.095	.084	.085	.08	.085	.089	.08	.075	.075	.07	.075	.06	.06	.055	.055	.06	.06	.06	.055	.057	.06
Diameter eye	.055	.056	.057	.05	.05	.05	.05	.055	.06	.055	.055	.055	.065	.06	.06	.055	.06	.06	.064	.055	.06	.06
Interorbital width	.075	.08	.08	.075	.08	.085	.08	.07	.07	.07	.06	.07	.06	.065	.065	.065	.06	.065	.06	.064	.06	.06
Depth head	.18	.185	.165	.185	.182	.18	.18	.165	.165	.17	.175	.16	.155	.155	.16	.155	.15	.16	.152	.15	.15	.15
Snout to occiput	.20	.225	.205	.21	.195	.215	.21	.21	.205	.205	.205	.205	.185	.19	.185	.18	.18	.19	.19	.19	.19	.195
Snout to dorsal	.485	.51	.51	.50	.505	.505	.50	.50	.505	.51	.495	.495	.465	.47	.475	.46	.475	.47	.48	.465	.455	.46
Snout to ventral	.56	.55	.58	.575	.585	.575	.58	.56	.59	.56	.58	.555	.55	.52	.55	.55	.545	.545	.52	.53	.55	.56
Length base of dorsal	.12	.132	.115	.12	.115	.115	.115	.12	.125	.12	.12	.115	.11	.12	.115	.11	.115	.11	.12	.105	.11	.11
Length base of anal	.085	.095	.085	.085	.09	.085	.085	.075	.08	.09	.09	.08	.085	.085	.09	.085	.09	.08	.085	.08	.078	.08
Height dorsal	.155	.18	.15	.16	.16	.145	.145	.135	.16	.16	.165	.15	.16	.175	.17	.155	.16	.15	.175	.16	.17	.165
Height anal	......	.14	.115	.115	.122	.115	.115	.11	.12	.105	.13	.12	.11	.12	.12	.11	.11	.10	.125	.115	.12	.11
Length pectoral	.175	.205	.18	.21	.19	.175	.185	.19	.18	.19	.19	.17	.195	.20	.19	.19	.19	.18	.205	.185	.195	.18
Length ventral	.15	.17	.13	.155	.14	.14	.145	.15	.15	.15	.15	.14	.135	.14	.15	.14	.13	.135	.15	.15	.15	.14
Length caudal	.. ..	.205	.175	.20	.185	.185	.18	.215	.21	.215	.21	.20	.24	.21	.24	.22	.22	.22	.22	.215	.23	.225
Dorsal rays	11	11	11	11	11	11	11	10	10	11	11	10	10	11	11	11	12	11	10	10	11	11
Anal rays	10	11	11	11	11	11	10	10	10	11	10	10	10	10	10	9	10	9	10	10	10	9
Scales lateral line	74	80	77	80	74	75	80	78	79	79	78	81	78	74	80	80	78	74	76	80	80	74
Scales above lateral line	11	10	10	10	10	10	11	11	10	11	11	10	10	9	10	11	9	10	10	10	10	10
Scales below lateral line	8	7	8	8	8	8	8	8	8	8	9	8	8	7	8	8	7	7	8	8	8	7
Scales before dorsal	30	33	34	34	31	31	34	33	33	33	32	33	30	30	30	30	31	30	33	31	32	31

The gill rakers numbered 6 to 8+12 to 14. The air bladder is large and extends the entire length of the abdominal cavity. The peritoneum is immaculate. There are 135 to 140 pyloric cæca, the posterior ones extending in a single series along the digestive tract. There are 8 branchiostegals.

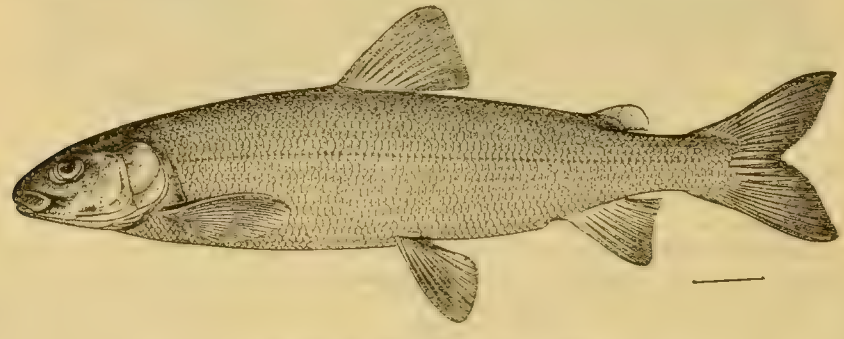
The growth appears to be about as follows:

	Length in millimeters.
4 years old	155 to 180
5 years old	200
6 years old	255 to 260
7 years old	280 to 437
8 to 10 years old	420 to 470

Old examples are fat and weigh 2½ pounds or more. Nothing was learned of the food of the species except that the stomachs of specimens caught during the months of January and February were stuffed with whitefish eggs. These were taken on the spawning grounds of *L. gemmifer* and *C. abyssicola*.

Coregonus abyssicola, new species. Bear Lake whitefish.

Small examples of this species (8 to 10 inches long) closely resemble those of *C. spilonotus* except that the latter are spotted. With increasing age the spots of *C. spilonotus* grow indistinct and finally disappear, while the maxillary and snout elongate, and the body becomes deeper. Consequently when the lack of spots fails to distinguish *C. abyssicola*, it may be easily separated from *C. spilonotus* by its much shorter maxillary.



Coregonus abyssicola. Bear Lake whitefish.

Local fishermen usually distinguish between spotted examples of *C. spilonotus* and this species, both of which they call herring, but they do not seem to suspect that the spotted fishes will grow to become the immaculate adults of *C. spilonotus*.

Mr. Stock reports that this species is taken in sufficient numbers to ship to near-by points.

It spawns from the latter part of January to early in March at a depth of about 100 feet.

Examples seen alive in August were moss-green above, silvery on the sides, and white beneath. These bleached in alcohol leaving very little dark pigment, while specimens taken during the breeding season are considerably darker, indicating that they are then much more highly colored.

Spawning fishes measure from 200 to 310 millimeters in length. The males are darker than the females, and the scales from the middle of the back to near the ventral surface bear mucous nodules. The females are smooth in most cases, an occasional one having small nodules on two or three rows of scales above and below the lateral line.

Type No. 83500, United States National Museum. Locality, Bear Lake near Fish Haven, Idaho. Length 310 millimeters. J. P. Stock collector.

Head 4.6 in length to base of caudal; depth 4.5; depth caudal peduncle 2.8 in head; snout 3.7; eye 5.2; interorbital width 3.4; maxillary 4.1; scales lateral series 78; between occiput and dorsal 30; above lateral line 8; below lateral line 7; dorsal 10; anal 11.

The body is relatively slender, head short, snout short and rounded, maxillary just reaching a perpendicular through anterior margin of orbit, the latter being very angular anteriorly, and extending well forward of the iris. Gill rakers 7+11, short, thick and pointed. Fins large, the pectorals and ventrals bluntly pointed; dorsal with a straight edge; adipose much larger than maxillary; caudal deeply cleft, the lobes pointed.

Color dusky above, silvery on the sides and below; no spots; scales on sides and below outlined with fine blackish dots; fins dusky, the caudal dark edged. Sex male. Each scale from the back to the level of the pectoral fin with a round, pearly mucous nodule.

In a series of specimens the scales in the lateral series number from 69 to 78; between occiput and dorsal fin 25 to 30; above lateral line 8 or 9; dorsal rays 10 or 11; anal 9 to 11.

MEASUREMENTS OF TEN EXAMPLES OF COREGONUS ABYSSICOLA.

Length of body.......mm..	258	234	211	235	233	245	213	223	180	206
	♂	♂	♂	♂	♂	♀	♀	♀	♀	♀
Length head	0.22	0.225	0.22	0.22	0.215	0.225	0.23	0.215	0.24	0.205
Depth body	.24	.24	.23	.235	.24	.25	.26	.25	.25	.24
Depth caudal peduncle	.08	.075	.07	.075	.075	.074	.072	.07	.08	.07
Length caudal peduncle	.13	.15	.145	.14	.16	.16	.16	.16	.155	.15
Length snout	.07	.08	.07	.075	.07	.075	.07	.075	.08	.07
Length maxillary	.05	.05	.05	.05	.052	.052	.05	.05	.055	.05
Diameter eye	.046	.05	.048	.045	.05	.047	.052	.046	.055	.05
Interorbital width	.065	.06	.065	.065	.063	.06	.06	.06	.06	.06
Depth head	.155	.16	.15	.15	.14	.155	.155	.15	.16	.14
Snout to occiput	.19	.21	.19	.19	.19	.19	.19	.19	.195	.18
Snout to dorsal	.495	.51	.48	.48	.475	.49	.48	.47	.47	.485
Snout to ventral	.54	.55	.54	.54	.535	.56	.55	.55	.54	.55
Length base of dorsal	.12	.125	.105	.10	.115	.10	.115	.10	.12	.10
Length base of anal	.095	.085	.08	.085	.10	.09	.08	.085	.085	.08
Height dorsal	.18	.18	.165	.16	.16	.16	.155	.155	.16	.16
Height anal	.13	.12	.105	.12	.12	.12	.115	.115	.11	.105
Length pectoral	.205	.21	.19	.185	.18	.20	.19	.17	.19	.19
Length ventral	.155	.15	.135	.14	.15	.15	.14	.13	.135	.13
Length caudal	.215	.215	.195	.20	.21	.20	.22	.195	.20	.21
Dorsal rays	11	11	10	10	11	10	11	10	11	10
Anal rays	11	10	10	10	10	10	9	11	10	10
Scales lateral line	76	71	74	75	75	75	72	69	71	72
Scales above lateral line	8	8	9	8	8	8	8	8	9	9
Scales below lateral line	7	7	7	7	7	7	6	6	7	7
Scales before dorsal	30	28	27	28	27	27	25	25	27	28

As indicated by the scales, the rate of growth appears to be as follows:

	Length in millimeters.
5 years old	180
7 years old	210 to 240
8 years old	250
9 years old	265
10 years old	300
13 years old	310

The gill rakers number 6 to 8+13 to 15 on the first arch; the cæca 73 to 78; branchiostegals 7 or 8.

FRESH-WATER MUSSELS AND MUSSEL INDUSTRIES OF THE UNITED STATES

By Robert E. Coker, Ph. D.
Assistant in Charge of Scientific Inquiry, U. S. Bureau of Fisheries

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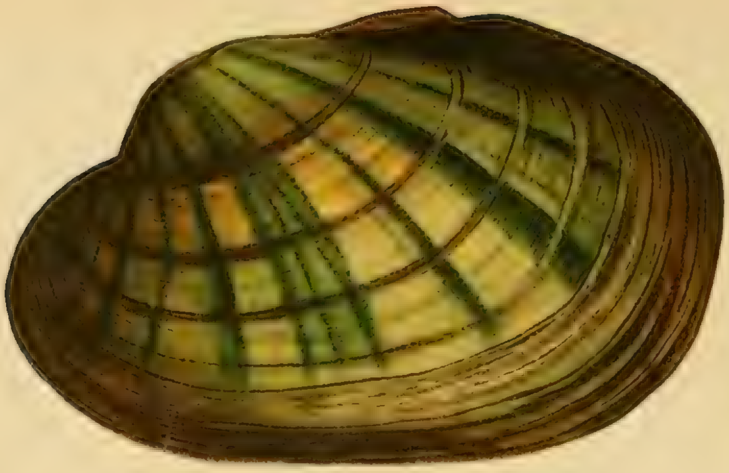

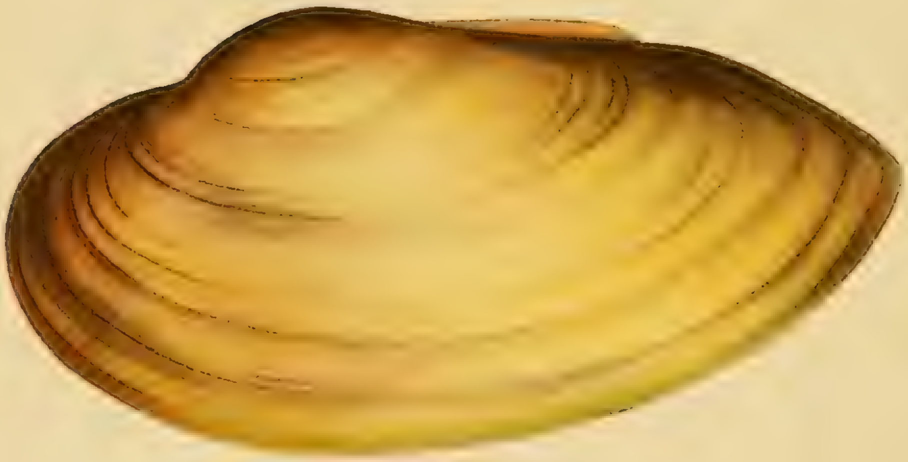

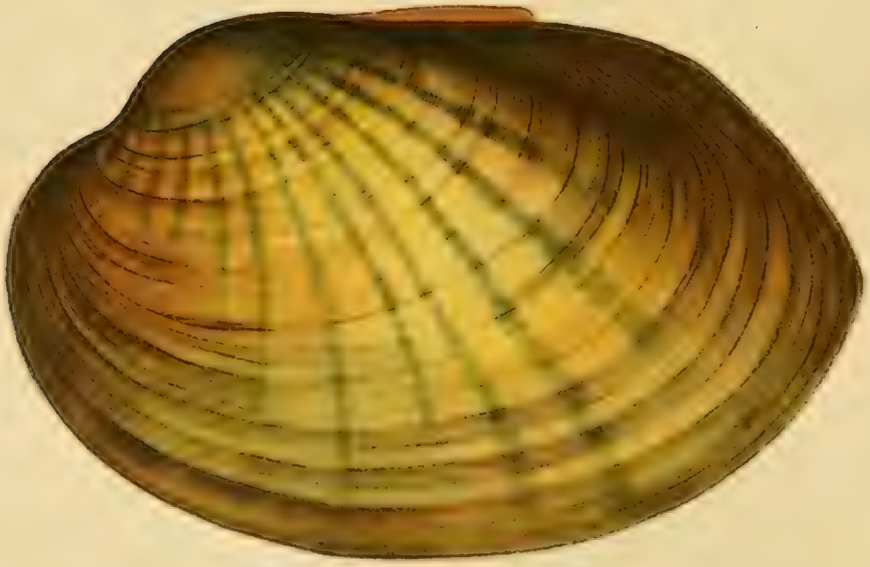

Lake Pepin mucket, female, *Lampsilis luteola* (Lamarck)
Yellow sand-shell, *Lampsilis anodontoides* (Lea)
Common river mucket, *Lampsilis ligamentina* (Lamarck).

FRESH-WATER MUSSELS AND MUSSEL INDUSTRIES OF THE UNITED STATES.

By ROBERT E. COKER, Ph. D.,
Assistant in charge of Scientific Inquiry, U. S. Bureau of Fisheries.

Part 1. COMMERCIAL FRESH-WATER MUSSELS.[a]

QUALITIES OF FRESH-WATER MUSSEL SHELLS.

Those who are familiar with only the common shellfish of the American seacoast or with the chalky, brittle shells of the streams of the Atlantic slope can have but little conception of the nature and quality of the mussel resources of the Mississippi Basin. In streams large and small throughout the greater part of this wide region, from the Appalachian Mountains to Arkansas and Dakota and from Louisiana to Mississippi, there is a wealth of pearly mussels of a variety of species, the shells of which are thick and firm, with clear, pearly luster, and in some cases displaying beautiful iridescence. Often the shells are strikingly ornamented with knobs and ridges, and the nacre, or mother-of-pearl, may be clear white, delicately tinted, or deeply colored with various shades of pink, salmon, red, or purple. The shells that are most striking in appearance are not, however, the most important. Of greatest value are those having the surface of the shell free from ornamentation or irregularities and with nacre of clear, lustrous white without stains or colors. It is these qualities, combined with a peculiar toughness or absence of brittleness or chalkiness, that lend to the fresh-water mussel shells the value they now possess as the basis for important manufacture.

Until the mussels assumed economic importance the several species were without distinguishing common names. With the development of the fishery the shellers on the several streams applied the common names which have suggested themselves as appropriate to the appearance of the shell or those which seem to have originated in a spirit of facetiousness. Since the shellers move from place to place, those of one State frequently mingling with those of distant regions, there has come to prevail a greater degree of uniformity of names of mussels than of the names of fishes.

As primary products or as by-products of manufacture the mussel shells are brought into commerce in the form of buttons, novelties, jewelry, chicken feed, road materials, composition marble, and otherwise. By far the chiefest use of mussel shells is, however, for the manufacture of pearl buttons, now worn by nearly every individual from the cradle to the shroud. The pearly mussels are also valuable in the production of pearls at a value of about $364,000 a year, but our concern in this paper is with the adaptability of the shells for the manufacture of buttons.

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[a] The author wishes to acknowledge his indebtedness to the late J. F. Boepple, shell expert at the Fisheries Biological Station at Fairport, Iowa, who prepared for the station in 1911 a series of memoranda on the commercial values of shells. These data have been of invaluable aid. H. W. Clark and J. B. Southall, of this station, and Ernest Danglade have been consulted with profit. Much information has been gained from time to time, too, through the generous advice of manufacturers, among whom special mention should be made of D. W. MacWillie of La Crosse, J. E. Krouse of Davenport, and Henry Umlandt of Muscatine. None of the persons named can be held responsible for any mistakes or for such opinions as are expressed. The color drawings of Plate I were made by Mrs. A. F. Shira; the photographs of shells are mostly by J. B. Southall.

When the manufacture of buttons from fresh-water shells began in 1891, the yellow sand-shell was the first to be used. As the industry grew, the supply of these shells soon proved to be insufficient. According to Mr. Boepple, the mucket, pocketbook, and black sand-shell were then brought into use, but it was not until 1894 that the niggerhead shell was tried. The niggerhead proved to be an excellent shell, with firm texture and beautiful luster, while a portion of it was found to be highly iridescent. This shell gained rapidly in favor and became the standard of price, while in time the valuable but less abundant yellow sand-shells became monopolized by the export trade.

It was the custom of the early shellers, as now, to gather the river-run of mussels and cook out the meats of all, but the shells of only two or three species were saved, while the others were thrown away as worthless. The shellers cooked out the entire lot of mussels in the hope of finding additional pearls and slugs. The shelling and the button industries, therefore, have a history similar to many other American industries in that the pioneers wasted large quantities of good material through lack of knowledge and experience and while secure in the thought that the supply was inexhaustible. In the course of time other shells were brought into use, until now 41 species in all are employed in the manufacture of buttons and novelties.

There are approximately 500 species of fresh-water mussels in the United States. The commercial species are practically restricted to flowing waters derived from the drainage of limestone regions. Such waters include most of the streams of the Mississippi Basin and some of those of the Great Lakes and Gulf drainages. Here the mollusk finds an abundance of lime, as well as of food, with the depths of water, currents, and other conditions favorable to its reproduction and growth. Many species of mussel occur in the streams of the Atlantic coast, but their shells are either chalky and eroded or else too small and too thin for commercial use. Fresh-water mussels of commercial value are not as yet known from streams of the Pacific slope.

An ideal button shell would have the following qualities: The nacre pearly white, or preferably iridescent, free from spots, stains, or colorings; the texture firm throughout, neither brittle nor chalky, nor yet too hard; the inner surface smooth; the outer surface free from ridges or protuberances; the thickness uniform, with low umbones or beaks, and tips relatively thick; the shape flattish, oval; the size sufficient to permit of cutting several blanks. There are, however, no ideal button shells to be found. Some, valuable for certain desirable qualities, are yet far from perfection in other respects. A few approach the ideal, but the same species is not always uniform in quality in different rivers nor even in different parts of the same river.

A given species may yield a good working shell in one river, while in another stream its shell shows hard and soft spots, stains, dullness of nacre, or other poor qualities. For example, the washboard of the upper Illinois River, while extra large, is badly stained; yet the same species, in the lower stretches of this river, though much smaller, is flatter and so free from spots as to make a much better material for buttons. The muckets of the Kankakee, Wabash, and upper Mississippi Rivers are of extra good quality, while in the Illinois and some other rivers they are scarce and of second quality.

An excellent illustration is afforded by the fat mucket. It is the most common shell of the lakes of the upper portion of the Mississippi Basin, but in these localities it is nearly always very thin, sometimes almost papery. In parts of the upper Mississippi it attains a large size, and has a shell of good quality and thickness except for the relatively thin tip (the hinder portion of the shell). In Lakes Pepin and St. Croix the same species is not only of the best quality, but of such degree of uniformity in thickness as to be practically tipless.[a]

A shell can not always be judged by its appearance. The Bureau, having a shell-testing shop at the Fairport station, makes a practice of testing out the shells submitted by the field parties. Pocketbook shells of exceptionally fine appearance received from the Sauk River proved upon test to be so brittle as to be worthless. Niggerhead shells collected in some lowland waters along the Mississippi in Louisiana had an appearance of first quality, but in the cutting test showed a chalky character and a tendency to split, which gave them a second-grade rating. It happens, too, that a shell having a nacre which is white upon the surface may be found in process of finishing to be discolored beneath.

Besides the useful shells, there are found in all rivers, but not in any uniform proportion, those which are useless on account of being too thin or discolored. Some of the most beautifully colored shells are of no commercial value.

VARIETIES OF COMMERCIAL SHELLS.

Most of the commercial fresh-water mussels, considered with regard to the quality of shell, fall into two main classes, which may be termed the *Quadrula* class and the *Lampsilis* class, giving to each class the name of the genus to which belong most of the common species exhibiting the characters of the class. There remain a few groups of species of less importance, which have little in common with the others and which may be classed together under the head of "Miscellaneous groups." Each class naturally divides itself into several groups, which may be conveniently designated by the name of the principal species of the group. It is rather significant that the classes and groups correspond approximately to the general plan of scientific classification. Mussels close in systematic relation possess, roughly speaking, similar qualities of shell, but this must not be taken as a universal rule. For our present purposes, we are not primarily concerned with the scientific classification, but it happens conveniently that general statements can be made regarding the natural history of the mussels of some of the respective groups.

In view of the large number of species used more or less for commercial purposes in the manufacture of buttons or novelties, it is somewhat difficult to decide which species to include. Especially is this the case since a number of mussels useless to the manufacturer have an importance in the production of pearls. In the following pages several species are discussed which are not at present of known economic importance, but it is believed that none is mentioned that is not familiar to fishermen in one region or another. Nearly all of the mussels mentioned will occasionally reach a factory along with other shells. The little rainbow shell (*L. iris*) is commonly mistaken by shellers for a young mucket: therefore we have mentioned *iris* in connection with the mucket in the hope of aiding fishermen to make the proper distinction.

---

[a] In the terminology of pearl-button manufacture a tip is a blank (unfinished button) less than one-twentieth of an inch in thickness, or that portion of the shell from which only blanks of such thinness are cut. In an ordinarily good shell not more than one-fourth of the area of the shell is tip. If the thickness of a shell is unusually well sustained in the hinder portion, the shell is without tip; at the other extreme a shell is spoken of as all tip, and such a shell is of no value. However, the term "tip" is somewhat differently employed by some manufacturers.

One can not grasp the significance of scientific names or appreciate the sense of scientific classification unless the remarkable fact of convergence is understood. This means that species of shells not closely related may yet take the same form in certain characters, as in the form and color of the shell. Let us take, for example, two species of mussels which are so much alike in external appearance that the novice can scarcely distinguish between them. Both are much compressed from side to side, possess very thin shells, and are commonly known as paper-shells. One of these, known to science as *Lampsilis gracilis*, seems to be nearly related both to the mucket and to the inflated pocketbook shell, *Lampsilis ventricosa*. The other compressed species, which is *Proptera lævissima*, is closely related to another pocketbook type of shell, the much-inflated *Proptera capax*. In all features of body structure and of life history, the two paper-shells possess relatively little in common, and the same may be said of the two pocketbooks. These are cases where appearances are deceiving not only to fishermen but to anyone who looks upon only external characters. A very obvious case of convergence is the familiar one of the pink heel-splitter *Lampsilis alata* and the white heel-splitter *Symphynota complanata*. In this case the resemblance is only on the outside, and a sheller will readily see the difference on the inner surface from the very distinct character of hinge and teeth in the two species (Pl. XXII).

It will materially simplify our discussion to dispose of paper-shells together and pocketbooks together, etc. Therefore, the commercial grouping is followed, but, as previously suggested, the deviation from scientific classification is not generally so wide as might be expected.

In the following pages the quality and distribution of the more common commercial species are considered.[a] The list immediately below indicates the relations of the various species, showing the order in which the different species are considered, and gives references to plates on which they are represented and to pages on which they are discussed. In the list the use of brackets indicates that a species is discussed, but is not regarded at present as of commercial value.

ORDER IN WHICH DIFFERENT SPECIES AND THEIR RELATIONS ARE CONSIDERED, WITH THE PLATE NUMBERS AND PAGES.

Class, group, and common name.	Scientific name.	Plate.	Page.
The Quadrula class:			
The niggerhead group—			
Niggerhead	Quadrula ebenus	II, III	20
	Quadrula solida	II	22
Long solid	Quadrula subrotunda	IV	22
Hickory-nut	Obovaria ellipsis	III	22
	Obovaria circulus		22
[Golf-stick]	[Obovaria retusa]		22
The pimple-back group—			
Pimple-back	Quadrula pustulosa	V	23
	Quadrula pustulata	VI	23
	Quadrula cooperiana	VI	23
Maple-leaf	Quadrula lachrymosa	VII	23
	Quadrula fragosa	VII	24
Monkey-face	Quadrula metanevra	VII	24
[Rabbit's foot]	[Quadrula cylindrica]	VII	24

[a] In the list and following descriptive account of commercial mussels, the scientific nomenclature of Simpson is followed.

ORDER IN WHICH DIFFERENT SPECIES AND THEIR RELATIONS ARE CONSIDERED, WITH THE PLATE NUMBERS AND PAGES—Continued.

Class, group, and common name.	Scientific name.	Plate.	Page.
The Quadrula class—Continued.			
The pimple-back group—Continued.			
[Purple pimple-back]	[Quadrula granifera]	VI	24
[Purple pimple-back]	[Quadrula tuberculata]	VI	24
[Three-horned warty-back]	[Obliquaria reflexa]	VI	24
The pig-toe group—			
Pig-toe	Quadrula undata	VIII	24
Ohio River pig-toe	Quadrula obliqua	VIII	25
Pig-toe	Quadrula plena	VII	25
Pig-toe	Quadrula pyramidata	XII	25
Flat niggerhead	Quadrula coccinea	IX	25
Wabash pig-toe	Quadrula rubiginosa	IX	25
The blue-point group—			
Blue-point	Quadrula plicata	X	26
Three-ridge	Quadrula undulata	X	26
Round-lake shell	Quadrula perplicata		26
	[Quadrula elliottii]		26
	[Quadrula neislerii]		26
The washboard group—			
Washboard	Quadrula heros	XI	26
Washboard	Quadrula boykiniana		27
[Bank-climber]	[Quadrula trapezoides]	XII	27
Buckhorn	Tritogonia tuberculata	XI	27
The Lampsilis class:			
The mucket group—			
Mucket	Lampsilis ligamentina	I, XIII	28
[Rainbow-shell]	[Lampsilis iris]	XIII	28
Southern mucket	Lampsilis ligamentina gibba	XIV	28
Higgin's eye	Lampsilis higginsii	XIV	29
	Lampsilis orbiculata	XIV	29
Fat mucket, Lake Pepin mucket	Lampsilis luteola	I, XV, XVI	29
Southern fat mucket	Lampsilis hydiana		30
Butterfly	Plagiola securis	XV	30
[Deer-toe]	[Plagiola elegans]		30
The pocketbook group—			
Pocketbook	Lampsilis ventricosa	XV, XVI	30
[Grandma]	[Lampsilis ovata]	XVII	31
[Pocketbook]	[Lampsilis capax]	XVII	31
[Purply]	[Lampsilis purpurata]	XVIII	31
	[Lampsilis multiradiata]	XVIII	31
The sand-shell group—			
Yellow sand-shell	Lampsilis anodontoides	I, XVI, XIX	31
Slough sand-shell	Lampsilis fallaciosa	XIX	32
Black sand-shell	Lampsilis recta	XIX	32
	[Lampsilis subrostrata]	XIX	32
Miscellaneous groups:			
The bullhead group—			
Bullhead	Pleurobema aesopus	XX	33
Fan-shell	Cyprogenia irrorata	XX	33
Dromedary shell	Dromus dromas	XX	33
[Kidney-shell]	[Ptychobranchus phaseolus]	XXI	33
The heel-splitter group—			
White heel-splitter	Symphynota complanata	XXII	33
Fluted shell	Symphynota costata		33
[Pink heel-splitter]	[Lampsilis alata]	XXII	34
[Rock pocketbook]	[Arcidens confragosus]	XXI	34
The elephant's-ear group—			
Elephant's ear	Unio crassidens	XXIII	34
Spike	Unio gibbosus	XXIII	34
Noncommercial species—			
[Floater]	[Anodonta grandis]	XXIV	35
[Slop-bucket]	[Anodonta corpulenta]		35
[Paper-shell]	[Anodonta suborbiculata]	XXVI	35
[Paper-shell]	[Anodonta imbecillis]	XXV	35
[Squaw-foot]	[Strophitus edentulus]	XXV	35
[Spectacle-case]	[Margaritana monodonta]	XXVI	35
[River pearl mussel]	[Margaritana margaritifera]	XXIV	35
[Paper-shell]	[Lampsilis gracilis]		35
[Paper-shell]	[Lampsilis lævissima]		35
[Paper-shell]	[Lampsilis parva]		35
[The Sphæriidæ]	(Species undetermined)	XXVI	36

QUADRULA CLASS.

This includes the niggerhead, the pimple-back, the blue-point, the washboard, and others of minor importance. Nearly all of the mussels thus classed together are short-term or summer breeders. This means that the eggs are fertilized and incubated in the gill pouches of the female, passed out to become parasitic upon fish, and liberated after the period of parasitism, all within a relatively short period of weeks or months and generally during the summer season. Most of these species are tolerably restricted in their parasitism, and for this reason, as well as on account of the short breeding season, they lend themselves less readily to propagation by artificial means. The chief dependence for their conservation must now be placed upon protective measures in order to insure a plentiful supply of spawners in nature, and, as is equally important, upon efforts to promote the abundance of the fishes upon which the mussels become parasitic. These mussels were not the first to be used and appreciated, but after coming into use their popularity grew until in recent years they have constituted the greatest portion of the raw material for manufacture. Other species of mussels fell into disfavor, but now, with the discovery of better material in the Lampsilis class, the pioneer mussels in commerce are again returning to favor.

From the best to the worst there is a wide extreme, but, generally speaking, Quadrula shells are harder and of better luster and iridescence than others; these superior qualities are doubtless associated with their comparatively slow rate of growth. The individual shells show greater extremes of thickness than Lampsilis mussels (such as the mucket) so that, in cutting and finishing buttons from them, there is a relatively high proportion of waste. In addition to the relative ease of propagation, therefore, there are several practical advantages in favor of the Lampsilis mussels.

NIGGERHEAD GROUP.

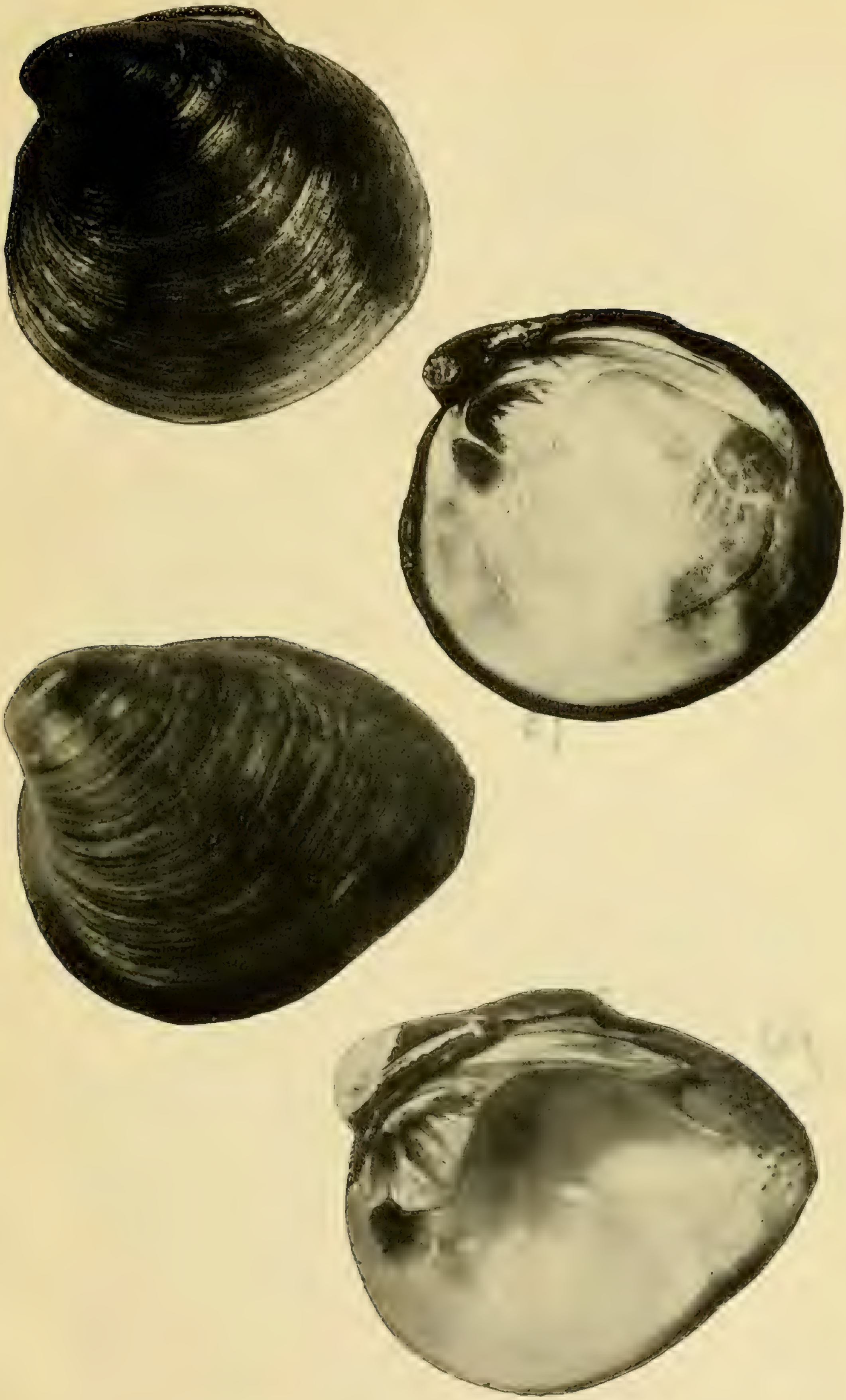
The shells of the niggerhead group distinguish themselves from all others of the Quadrula class by combining a smooth exterior surface with a high degree of uniformity of quality. The niggerhead takes first place among the Quadrulas.

The niggerhead, *Quadrula ebenus* (Lea) (Pls. II and III) came to be the mussel most sought, and a few years ago, at least, it was the common standard of value. The better shells were suited to the export demand and accordingly have advanced in price. Its preeminent qualities, as compared with other species of this and the following groups, are its clear, pearly luster (equaled by only a few), the relative thickness of the iridescent portion, and its abundance in favorable streams. The nacre is of fine regular grain and lustrous white, except where iridescent. In buying mussels for button manufacture the price is often based upon the percentage of niggerheads.

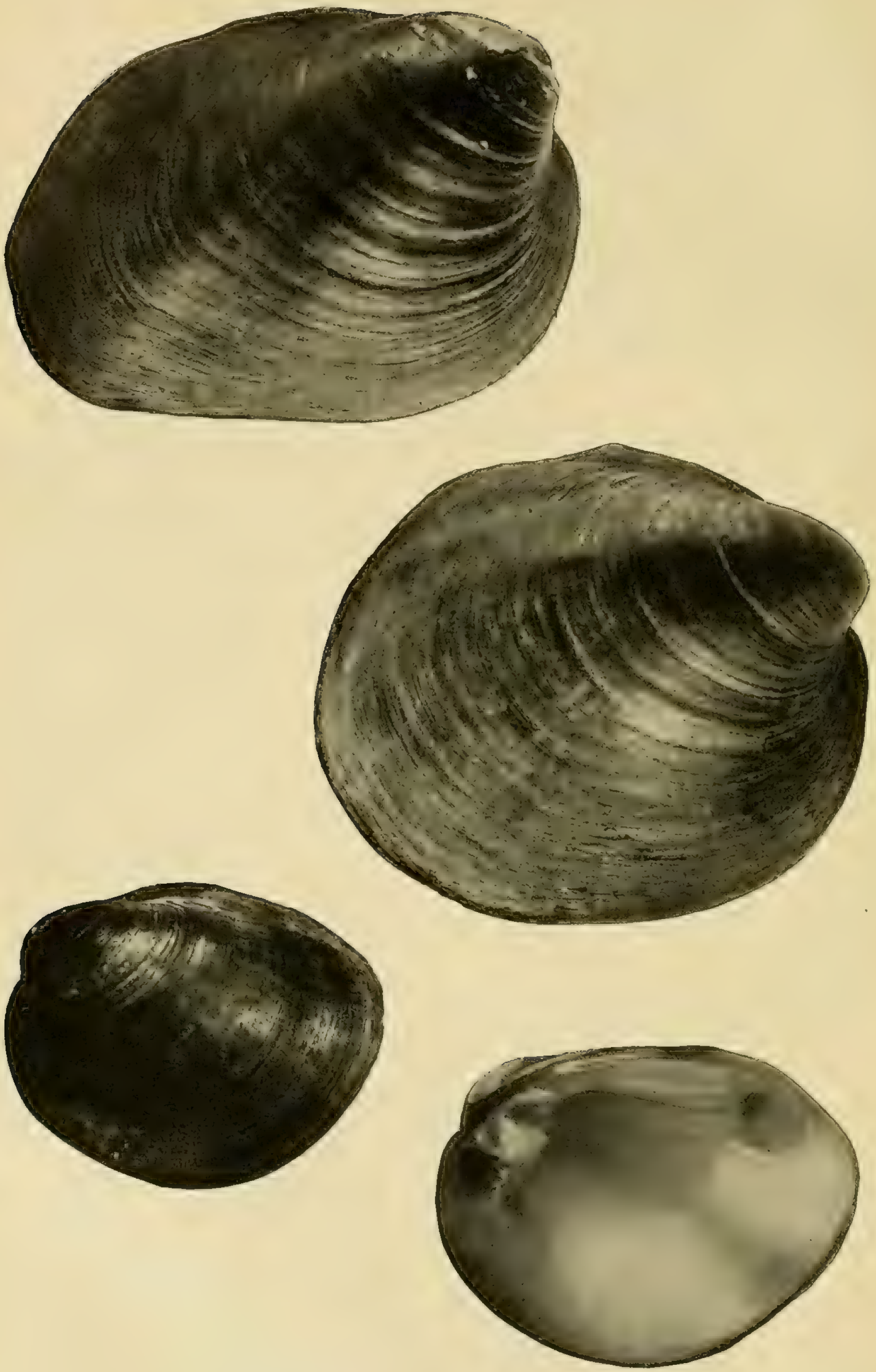
The niggerhead forms 80 per cent of some mussel beds of the Mississippi but is not so common in the tributaries. It is usually restricted to the larger streams. It was once thought that the Mississippi niggerheads were better than any other, but this is not always the case. Some of the niggerheads from Arkansas are unsurpassed, especially those of the St. Francis River. Like other mussels, the niggerhead varies quite a little in form. Those which are more flat and round are preferred (Pl. III, middle shell), as compared with examples which are elongate (Pl. III, upper shell) or in which there is a noticeable step-off from the thicker forward and central portions to the thinner hinder third of the shell. The shells formerly taken in the Des Moines Rapids above Keokuk were of the better character.

A notable feature of the niggerhead mussel is the markedly iridescent hinder portion of the shell, and the thickness of this portion is generally better sustained in the niggerhead mussel than in any other species displaying iridescence. The buttons finished from

PLATE II.



Upper pair: Niggerhead, *Quadrula ebenus* (Lea), from Mississippi River. (See p. 20.)
Lower pair: *Quadrula solida* (Lea), from Mississippi River. (See p. 22.)



Upper and middle: Niggerhead, *Quadrula ebenus* (Lea), from Mississippi River. (See p. 20.)
Lower pair: Hickory-nut, *Obovaria ellipsis* (Lea), from Mississippi River. (See p. 22.)

the hinder portion of the shell constitute the shiny backs, as they were originally called, or iridescents, as they are now more generally termed. The iridescents are of exceptional quality and command a substantial premium in the market, where they rival the high-priced buttons made from so-called "ocean pearl," or the shells of certain marine mollusks. While it is usually customary to finish the face of the blank which corresponds to the inner surface of the shell, a better product is obtained with iridescent buttons if the face corresponding to the outer surface, or back, of the shell be finished to make the face of the button.

There is some difficulty not only in keeping the two sorts of blanks separate, but also in insuring that the blanks are cut entirely from the iridescent portion instead of partly from the iridescent and partly from the lustrous white surface. Since comparatively few are obtained in any case, it is not a general practice to cut for iridescents, and most of the iridescents of commerce are cut and finished by chance, as it were, and simply sorted out in the process of grading the finished buttons. A prominent manufacturer stated at one time that a much higher price could be obtained for iridescents if one could obtain a sufficient number upon which to build a line of trade. As it is, iridescents are generally an incidental product.

As compared with shells like the Lake Pepin mucket, or the ordinary river mucket, there is considerably more waste in niggerheads, on account of the heavy hinge and teeth and the relative differences of thickness between the forward and hinder parts of the shell. For this reason particularly, relatively small niggerhead shells, from 1.5 to 2.5 inches in greatest dimension, are preferred. Such are the shells taken in the Mississippi about Le Claire, Iowa, and in the White and St. Francis Rivers of Arkansas. In the early years of mussel fishery in any niggerhead stream, a large proportion of heavy, coarse shells were taken, and they were much less desirable. Owing to the generally depleted condition of most niggerhead beds, few large shells are now taken, but occasional specimens are found that are upward of 4 inches in length. Some of these are of excellent quality, but there is a great deal of waste in cutting them, as most of the blanks are very thick and have to be ground to the desired degree of thinness for buttons.

The relative economy in use of niggerhead mussels of different sizes is shown by the following record of tests as to number of blanks per shell and per ton:

SIZES, WEIGHTS, AND BUTTON PRODUCTION FOR NIGGERHEAD SHELLS (APPROXIMATE FIGURES).

Longest dimension.		Number of mussels per ton.	18-line blanks per single shell.	Quantity of blanks per ton.
Greater than—	Less than—			
Inches.	*Inches.*			*Gross.*
3/4	1	174,000	....	....
1	1 1/4	110,000	....	....
1 1/4	1 1/2	55,000	....	....
1 1/2	1 3/4	33,000	1-2	688
1 3/4	2	26,000	3	1,083
2	2 1/4	20,000	4	1,111
2 1/4	2 1/2	15,000	5	1,042
2 1/2	2 3/4	10,500	7	1,021
2 3/4	3	8,500	[a] 8	944
3	3 1/2	6,200	[a] 10	868
3 1/2	4	4,000	[a] 12	667
4	....	3,200	[a] 14	622

[a] At the time of making this table only a few of the larger-sized shells were available, so that the estimates of blanks are less accurate for these sizes.

Because of the demand for the smaller sizes, a large number of very small shells are being marketed, many of them entirely too small to be of any service whatever.

In the years just preceding 1914 there was a growing export trade in niggerhead shells of small and medium size, the price reaching $40 per ton on the river. In consequence of the export demand, the domestic market was diverted more and more to the inferior grade of shells. Since 1914 the domestic market has found a larger supply of the niggerheads available to it, and consequently the domestic demand for lower-grade shells has declined. During several years prior to 1914 the prices paid for niggerhead shells for domestic manufacture varied from $18 to $27 per ton; in 1919 the price per ton ranges from $40 to $80.

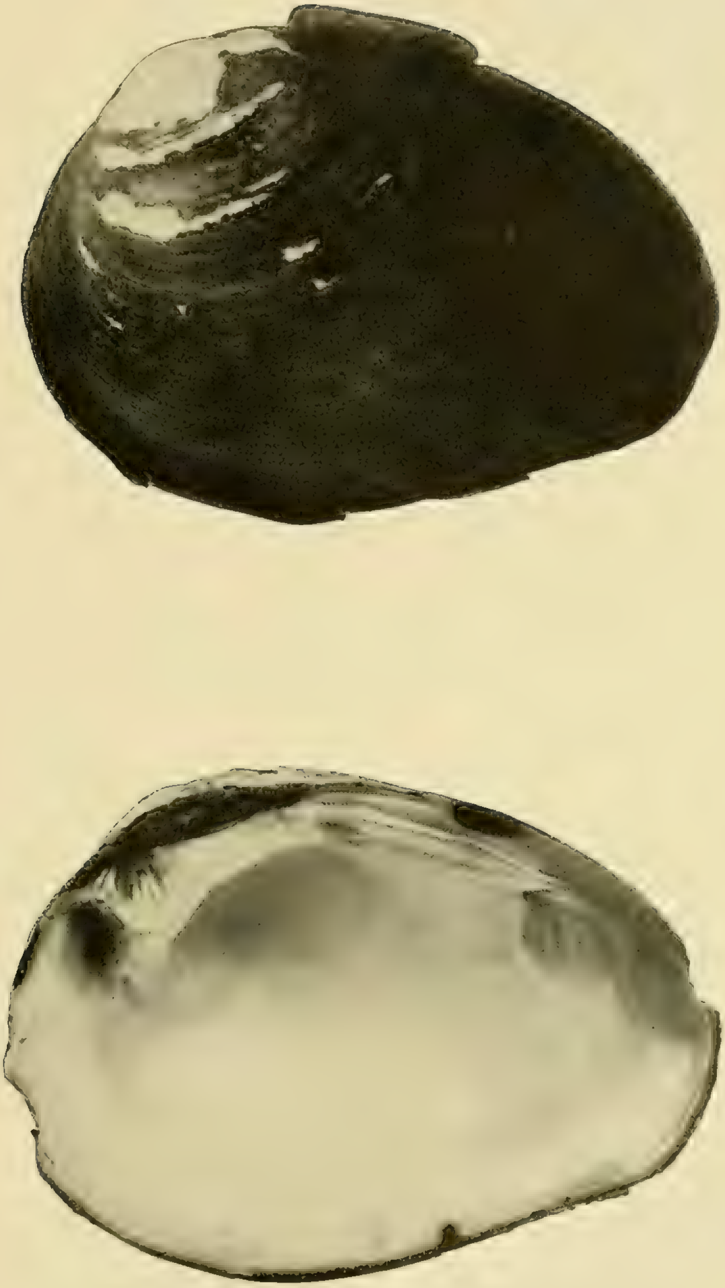
The niggerhead mussel appears to have two spawning periods, one in spring and another in early and midsummer, but the periods are yet to be accurately defined if they are actually distinct. Like other mussels, the niggerhead is parasitic upon fish, but the only species of fish known to carry it successfully is the river herring, *Pomolobus chrysochloris*. Since this fish is characteristic of deeper and swifter streams, the distribution of the niggerhead mussel is restricted accordingly. Even in such a large but generally sluggish river as the Illinois the niggerhead is rare, and Forbes and Richardson report that the river herring is very uncommon in that stream. There are many herring in Lake Pepin, but few niggerheads are taken there, so that other conditions must be unfavorable in this place. The niggerhead is generally found in hard, gravelly or rocky bottoms, and it is very abundant in such rapids as occur on the Mississippi. Its distribution is, however, rather hard to define, since some of the larger examples have been taken in deep and slowly flowing water. The White River of Indiana, the Scioto River of Ohio, and the Duck River of Tennessee have yielded some particularly large shells.

Quadrula solida (Lea) (Pl. II) is very like *Quadrula ebenus* and is generally regarded by mussel fishermen as the same. The material is equal to that of the niggerhead. Although widely distributed through the Mississippi Basin, the mussel is relatively rare and small and can not be rated as of much importance.

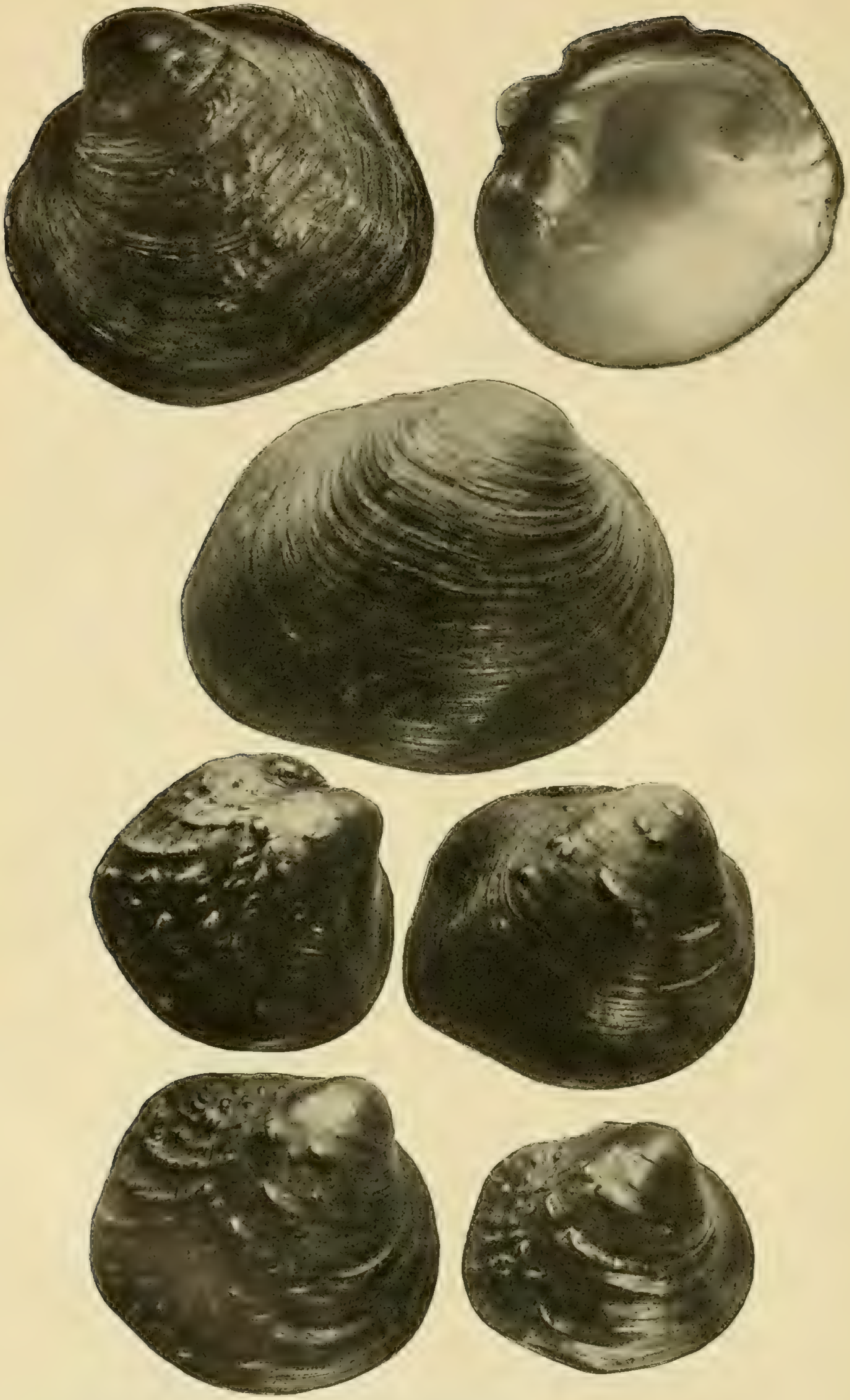
Quadrula subrotunda (Lea) (Pl. IV) is found in the Ohio, Cumberland, and Tennessee River systems. It resembles the niggerhead, and the adults are difficult to distinguish from the latter. At Clarksville, Tenn., it is called the "long solid," and is regarded as one of the best button shells of the lower Cumberland.

The hickory-nut, *Obovaria ellipsis* (Lea) (Pl. III) must be grouped with the niggerhead in respect to commercial qualities, although it is not closely related to it. This is perhaps the only conspicuous case in which different mussels agree closely in quality of shell while being rather distantly related in systematic characters. The hickory-nut mussel possesses a shell of essentially the same quality as the niggerhead and has sometimes been called the Missouri niggerhead. The mussel differs from the Quadrulas as a class in being a long-term breeder, carrying the young in the marsupial pouches over the winter period.

Closely related species are *Obovaria circulus* (Lea) and *Obovaria retusa* (Lamarck). The former is found principally in the southwestern portion of the basin. It is too small to be of much commercial significance, but will yield a few small blanks. The golf-stick, *Obovaria retusa* (Lamarck), is found in the Ohio, Cumberland, and Tennessee systems. Wilson and Clark report that it attains a rather large size in the Cumberland, "but the



Long solid, *Quadrula subrotunda* (Lea), from Cumberland River. (See p. 22.)



Pimple-back, *Quadrula pustulosa* (Lea), from Mississippi River, illustrating diversity of this species in form and sculpture. (See p. 23.)

deep purple of that portion of the nacre within the pallial line makes it valueless for buttons."

PIMPLE-BACK GROUP.

The better shells of this group have the same general qualities as the niggerhead. The best are inferior to the niggerhead only in that the backs are rough or warty, and the thickness of the tip is less well sustained. The luster is fine, and a portion of the shell is iridescent. The poorer shells of the group are worthless because of color of nacre, shape, or some other objectionable quality.

Like the niggerhead, they are short-time (summer) breeders and tolerably restricted in parasitism, as far as is known. Unlike the niggerhead, they rarely, if ever, occur in such numbers as to constitute the principal species in a mussel bed.

The pimple-back, *Quadrula pustulosa* (Lea) (Pl. V), is distributed throughout the whole Mississippi Basin in different forms and sizes but does not often attain a length greater than 2.5 inches. It occurs mixed in with other species and sometimes forms 10 per cent of the mussels in the beds. It is one of the best mussels of the Illinois River. It varies greatly as regards the size and number of pustules and rarely displays an almost entirely smooth shell. Its diversity of form is well illustrated by the several figures in Plate V.

In the earlier years of the industry the pimple-back was not used. The workmen did not like it on account of the pustules on the back, which made it difficult to cut. Later, as button-making material became scarcer, it came into use and is now bought and worked up along with the niggerhead, having the same market value.

The texture is firm, and the shell has a tolerably uniform thickness; since its thickness diminishes rather uniformly toward the tip, it can be worked up economically. It is principally used for small-sized buttons. The color of the nacre is lustrous white, and there is a fine iridescence in the hinder portion.

The pimple-back spawns in early summer and midsummer, and the glochidia are parasitic, chiefly upon several species of catfish.

Quadrula pustulata (Lea) (Pl. VI) is like *pustulosa* but is smaller and with fewer warts. It is comparatively rare and is not distinguished commercially from *pustulosa*.

Quadrula cooperiana (Lea) (Pl. VI) is a more southern form of pimple-back found in the Cumberland and Tennessee systems. It is called pimple-back, but, unlike the northern form, the nacre may be white or from a pale to a deep shade of pink. A blank of from 30 to 36 lines can be cut from the white shells.

The maple-leaf, *Quadrula lachrymosa* (Lea) (Pl. VII), is not found in great quantities but occurs in small numbers among other mussels; for this reason it was once known as the "stranger." The material is of a good, white luster and firm texture, but, owing to the thin tips, about half of the blanks can be used only as "tips," which is the commercial term for blanks less than one-twentieth of an inch in thickness.[a] A small proportion of iridescents is obtained, and, but for the thinnish tips and knobby back, the shell would be equal to that of the niggerhead. When found in considerable numbers in the shell piles at the cutting plants they are sometimes sorted out and cut separately.

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[a] See footnote, p. 17.

The shells are of about the same size as the niggerhead. Those 2.5 to 3 inches long are fairly large. Mr. Boepple reported that the Scioto and Duck Rivers yielded examples of maple-leaf 4 to 5 inches long. The maple-leaf mussels probably spawn in early summer and midsummer.

Quadrula fragosa (Conrad) (Pl. VII) is a very rare species of the maple-leaf, more quadrate in form than *Quadrula lachrymosa;* while *Tritogonia nobilis* (Conrad), having a similar external appearance, is confused with the maple-leaf.

The monkey-face, *Quadrula metanevra* (Rafinesque) (Pl. VII), is found in relatively small numbers. It occurs infrequently in the large mussel beds, but is usually found near the bank or outside the main beds. Owing to the large pustules and the very uneven outer surface it is difficult to cut, but with careful handling it may be cut into a few blanks of small size which are of excellent quality. The shell is often used to advantage for cutting one 24 or 30 line button from each shell. In value the shell is sometimes classed with pig-toes. The spawning time is early or midsummer.

The rabbit's foot, *Quadrula cylindrica* (Say) (Pl. VII), is a very long and narrow form that is familiar to the fishermen of the southern portion of the Mississippi Basin. It is too narrow, convex, and uneven of surface to be of value for button manufacture.

One or the other of the purple pimple-backs, *Quadrula granifera* (Lea) (Pl. VI) and *Quadrula tuberculata* (Rafinesque) (Pl. VI), is found in most large rivers of the Mississippi and Great Lakes Basins, but they are not generally distinguished. The species *tuberculata* is flattish and is probably found more often in the smaller or tributary streams. Both species are found in small numbers scattered among others. Owing to the purple color of the nacre, the shells have no commercial value. The layers are said to split apart in cutting. The shells have a very attractive appearance and will take a beautiful polish when finished as souvenirs. The mussels are of value in the rivers, since they produce a relatively high number of pearls. Scarcely a *tuberculata* could be taken in the Grand River in Michigan in 1909 without finding some sort of pearl formation. The spawning period is early summer.

The three-horned warty-back, *Obliquaria reflexa* (Rafinesque) (Pl. VI), is not at all closely related to the pimple-backs or purple warty-backs. It has one row of large knobs on each shell, and the knobs are remarkable in that those of the two sides are not opposite, but alternate in position; the species can not, therefore, be mistaken for any other.

The three-horned warty-back is found in small quantities along with other mussels. The forward portion of the shell is thick, the tip thin. The form and the knobs are objectionable, and the size is not large, but the texture is good, and the nacre is clear and white and makes first-grade button material.

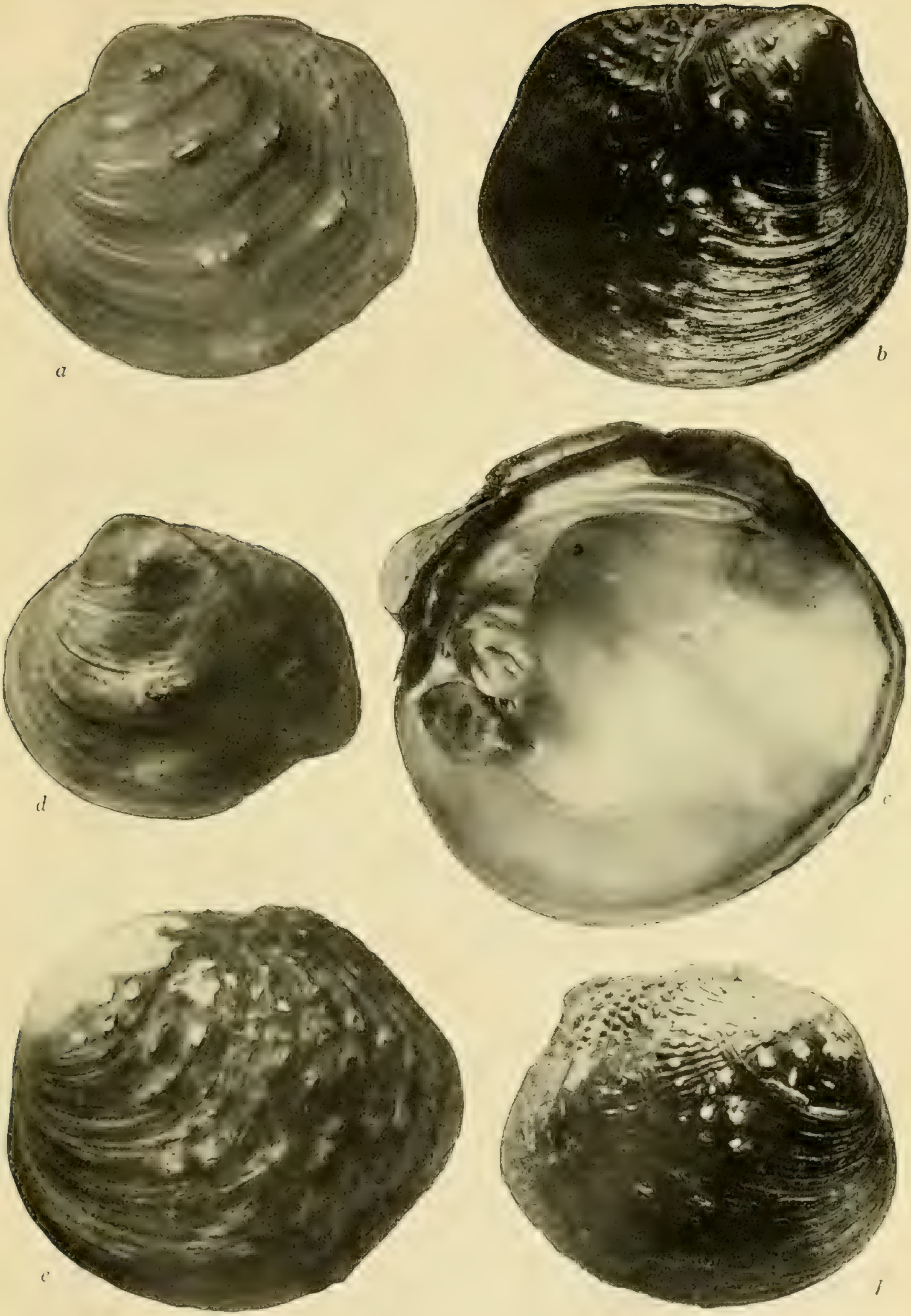
The species is widely distributed in the Mississippi drainage and elsewhere. It appears to be a summer breeder.

PIG-TOE GROUP.

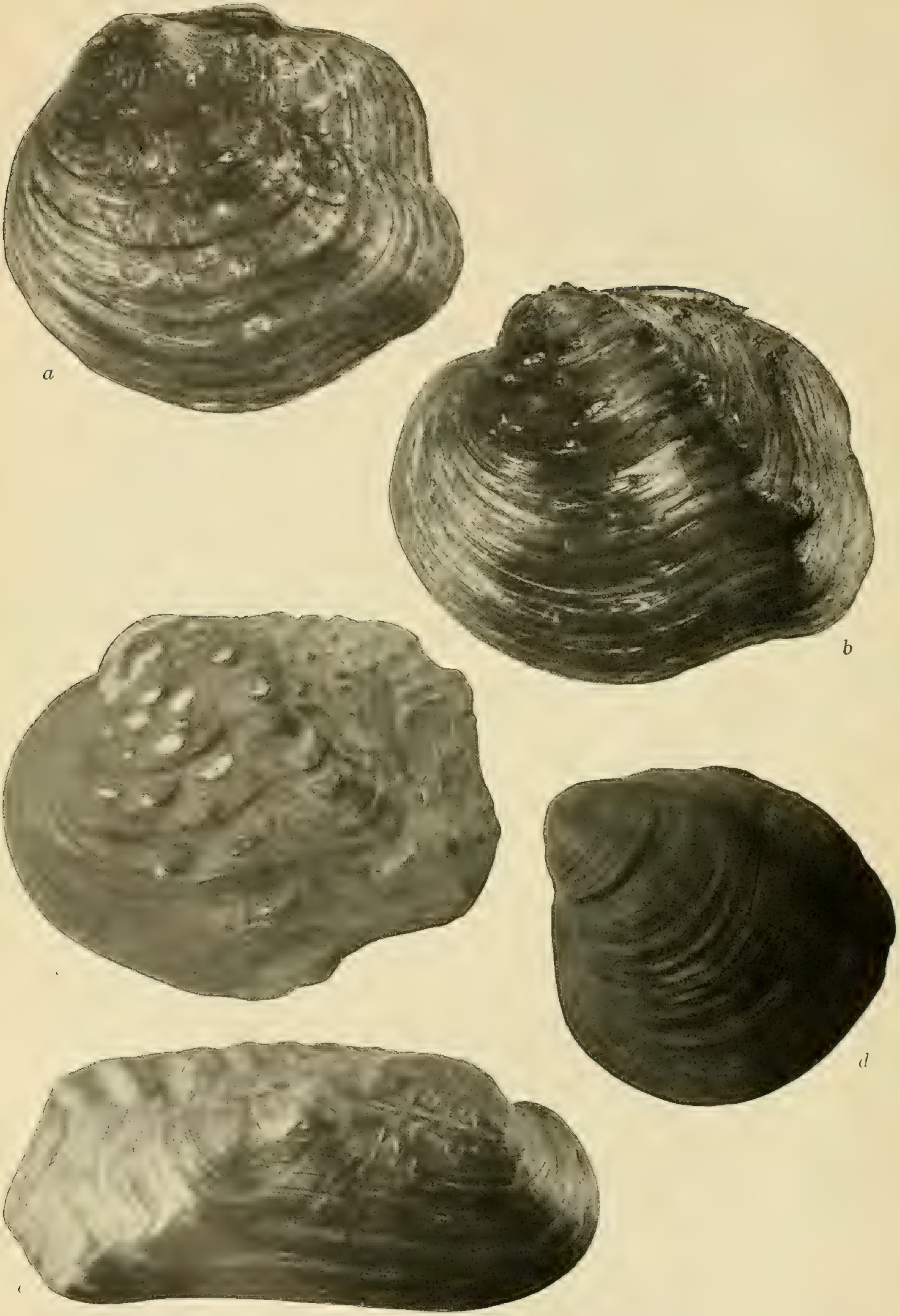
This group is rather limited both in variety of species and, except in certain streams, in general abundance of the mussels. None of the mussels is of the best quality.

The pig-toe, *Quadrula undata* (Barnes) (Pl. VIII), is found in small quantities, principally in the Mississippi, and also in some of its tributaries. White River, Ind., has examples of unusually large sizes. While the material is somewhat similar to that

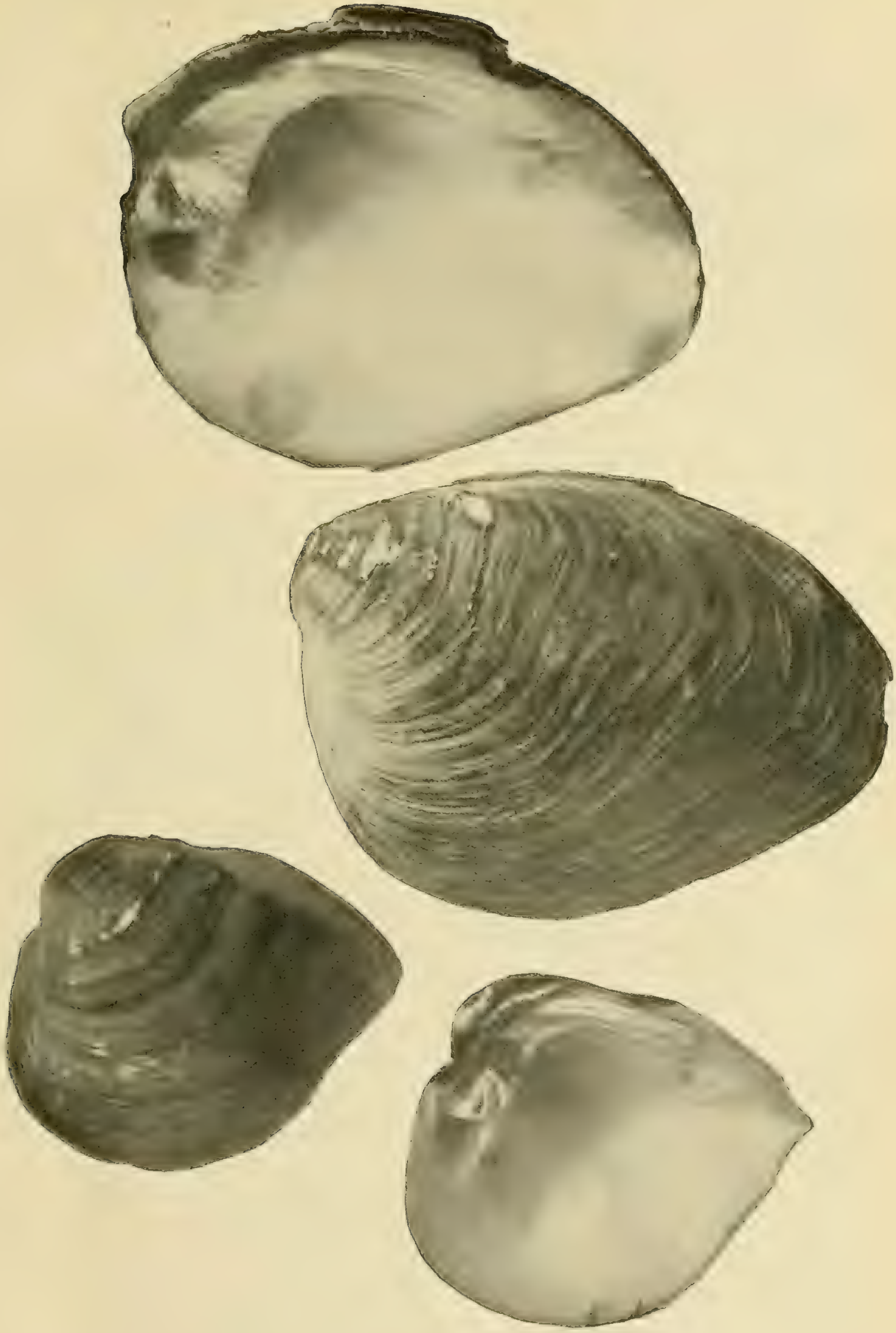
PLATE VI.



a, Pimple-back, *Quadrula pustulata* (Lea) (p. 23); *b* and *c*, purple pimple-back, *Quadrula granifera* (Lea), from Mississippi River (p. 24); *d*, three-horned warty-back, *Obliquaria reflexa* (Rafinesque) (p. 24); *e*, pimple-back, *Quadrula cooperiana* (Lea), from Cumberland River (p. 23); *f*, purple pimple-back, *Quadrula tuberculata* (Rafinesque) (p. 24).

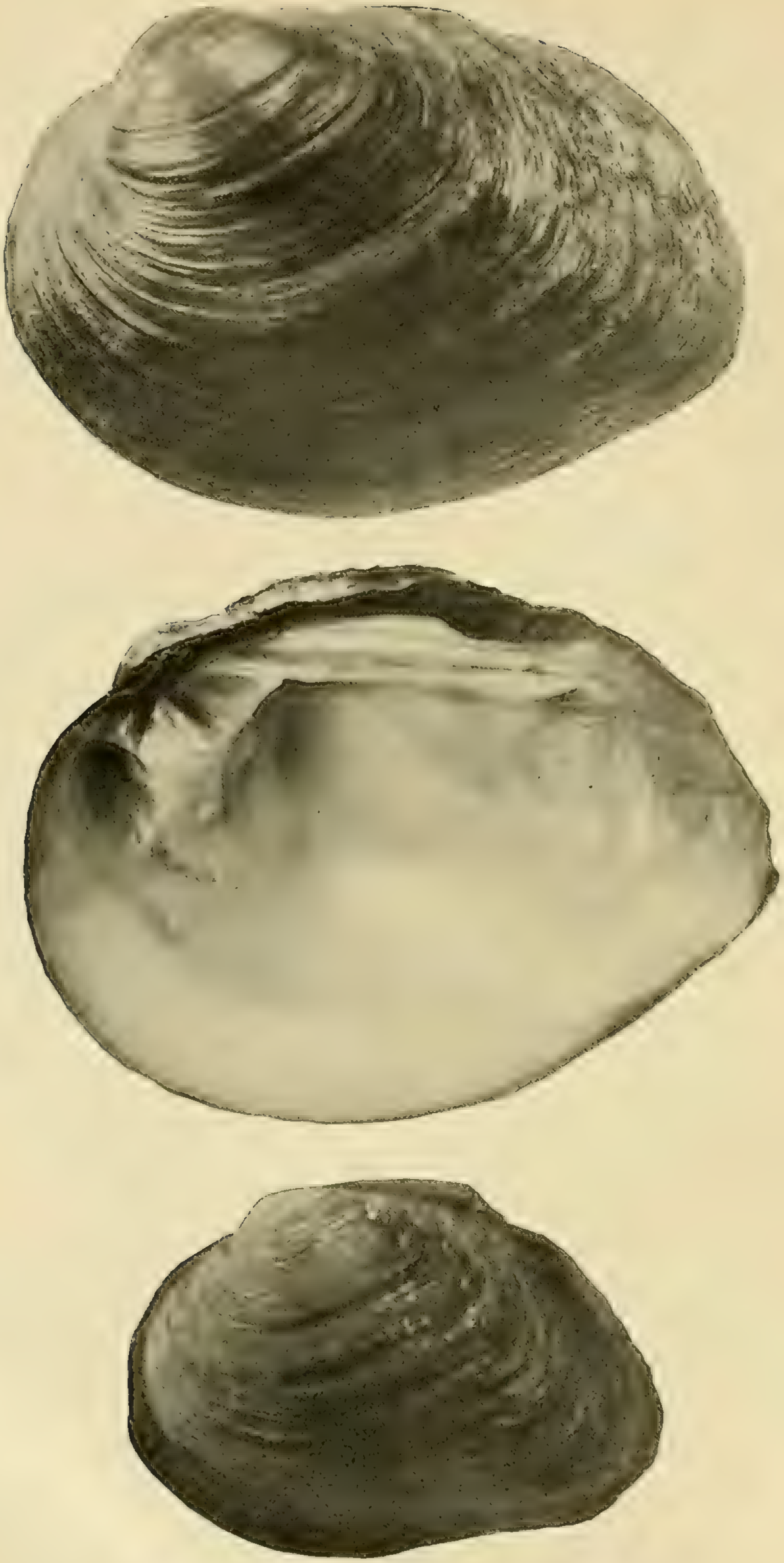


a, Monkey-face, *Quadrula metanevra* (Rafinesque) (p. 24); *b*, maple-leaf, *Quadrula lachrymosa* (Lea) (p. 23); *c*, maple-leaf, *Quadrula fragosa* (Conrad), from Ohio River (p. 24); *d*, pig-toe, *Quadrula plena* (Lea), from Cumberland River (p. 25); *e*, rabbit's foot, *Quadrula cylindrica* (Say), from White River, Ark. (p. 24).



Upper pair: Ohio River pig-toe, *Quadrula obliqua* (Lamarck), from Ohio River. (See p. 25.)
Lower pair: Pig-toe, *Quadrula undata* (Barnes), from Illinois River. (See p. 24.)

PLATE IX.



Upper pair: Flat niggerhead, *Quadrula coccinea* (Conrad), from Fox River. (See p. 25.)
At bottom: Wabash pig-toe, *Quadrula rubiginosa* (Lea), from Cedar Creek, Ind. (See p. 25.)

of *Q. ebenus*, its commercial value is not of first rank; the shell can not be worked up as economically as that of some other species and is usually cut into small-sized buttons. The pig-toe (formerly called *Quadrula trigona*) is a summer breeder.

Ohio River pig-toe, *Quadrula obliqua* (Lamarck) (Pl. VIII), is the commonest mussel in the Ohio River. It is found throughout its entire length as far as mussel beds extend. It often forms 80 per cent of the mussels in a bed. In some places in the Cumberland River this is the most common mussel, and the shells from the Cumberland River are superior to those of the Ohio. It is found also in the Illinois River, but is rarely, if ever, seen in the Mississippi.

The commercial value of its shell is not high. When first marketed from the Ohio River it brought only $1 to $2 per ton, and buyers were difficult to obtain at that price. In 1910 the price reached $8 per ton, but it has been higher since ($12 to $13 in 1914, and about $30 in 1919). The material has a poor luster and is chalky, and only the butt part of the shell can be used, as the iridescent portion of the shell is too thin. The nacre is often marked with green spots, and many shells are eroded at the umbones, these qualities being more evident in the shells from the upper portion of the river.

Quadrula plena (Lea) (Pl. VII) and *Quadrula pyramidata* (Lea) (Pl. XII) are two species that are distinguished taxonomically, but they can not be differentiated commercially from the other pig-toes.

The flat niggerhead, *Quadrula coccinea* (Conrad) (Pl. IX) and the Wabash pig-toe, *Quadrula rubiginosa* (Lea) (Pl. IX), are found principally in the small rivers. Both species are reported from the Grand River, Mich., and *coccinea* is common in the James River, S. Dak. They are not uncommon in the small outlets of lakes of the northern States. While the extreme forms are readily recognized, the two species run into each other (in external appearance), so that they are often confused. *Rubiginosa* has a pronounced posterior ridge. In shape the shells are sometimes rather circular (as is especially true of *coccinea*) or rhomboidal. They are more compressed than the ordinary run of niggerheads or pig-toes and have a relatively light-colored epidermis. The shells are somewhat puzzling to fishermen but are often called flat niggerheads or thin niggerheads. They are not, however, closely related to the niggerheads in scientific characters or commercial qualities.

Mr. Southall states that the nacre is sometimes rather soft, like the pig-toe, and sometimes very hard, like the bullhead (*Pleurobema æsopus*). It so happens that *coccinea* (but not *rubiginosa*) is placed by Dr. Ortmann in the genus *Pleurobema*. It is probable, therefore, that the commercial qualities, as well as the scientific positions of the two species, are quite distinct; but, in the lack of final information and with the present confusion in common parlance, they are mentioned together. The nacre of both species is of fair quality, but the iridescent part is too thin to be used. *Coccinea* often has a pink nacre, and in this case it is sometimes called "pink niggerhead."

The spawning times of both species are probably early summer and midsummer.

BLUE-POINT GROUP.

We come now to species that are much larger in size, always with rough, ridged backs and with a quality of nacre somewhat inferior to the shells of the niggerhead. Many of them are well esteemed, especially because so many blanks can be cut from the single shell, and because they are adapted for the larger sizes of buttons.

The species are not so restricted in parasitism as the niggerhead and the pimple-backs, and *plicata*, at least, is carried by several of the game fishes.

The blue-point, *Quadrula plicata* (Say) (Pl. X), and the three-ridge, *Quadrula undulata* (Barnes) (Pl. X), two very similar mussels, called by the mussel fishermen blue-point and three-ridge, are among the most widely distributed species in the whole Mississippi Basin, being found in most of the rivers and larger creeks in different sizes and forms. *Plicata* is the thicker species, with heavier umbones, common in the deeper and more sluggish waters, while *undulata* is flattish and characteristic of headwater or tributary streams. The species seem to intergrade, so that it is frequently difficult or impossible to distinguish them. The clammers do not seem to recognize the two species, but apply the term three-ridge or blue-point indiscriminately.

Generally speaking, these mussels, even when clear of spots, work with a good deal of waste, on account of the heavy hinge and teeth, and they yield a considerable number of second and third grade buttons, although some buttons of very good quality are also produced, including a few iridescents. Blue-points, three-ridges, and washboards (see below) were worth about $12 per ton in 1914, and about $30 in 1919.

The commercial value of the shells varies greatly in different rivers and creeks. In the Mississippi River, for example, the young mussels can be sold with the niggerheads. The value of the shell decreases as the mussel grows older. The shell loses iridescence and becomes more brittle and hard, and consequently difficult to work up; the layers lose their firmness of attachment, so that they split off easily. Old shells, moreover, are frequently spotted. It is found in manufacture that the iridescence of tips from these shells is enhanced by the processes of bleaching. These mussels spawn in midsummer.

In the streams of the gulf drainage in Florida, Georgia, and westward these species are replaced by *Quadrula perplicata* (Conrad), *Quadrula elliotti* (Lea), and *Quadrula neislerii* (Lea). *Quadrula perplicata* occurs in the Cumberland under the common name of round-lake shell.

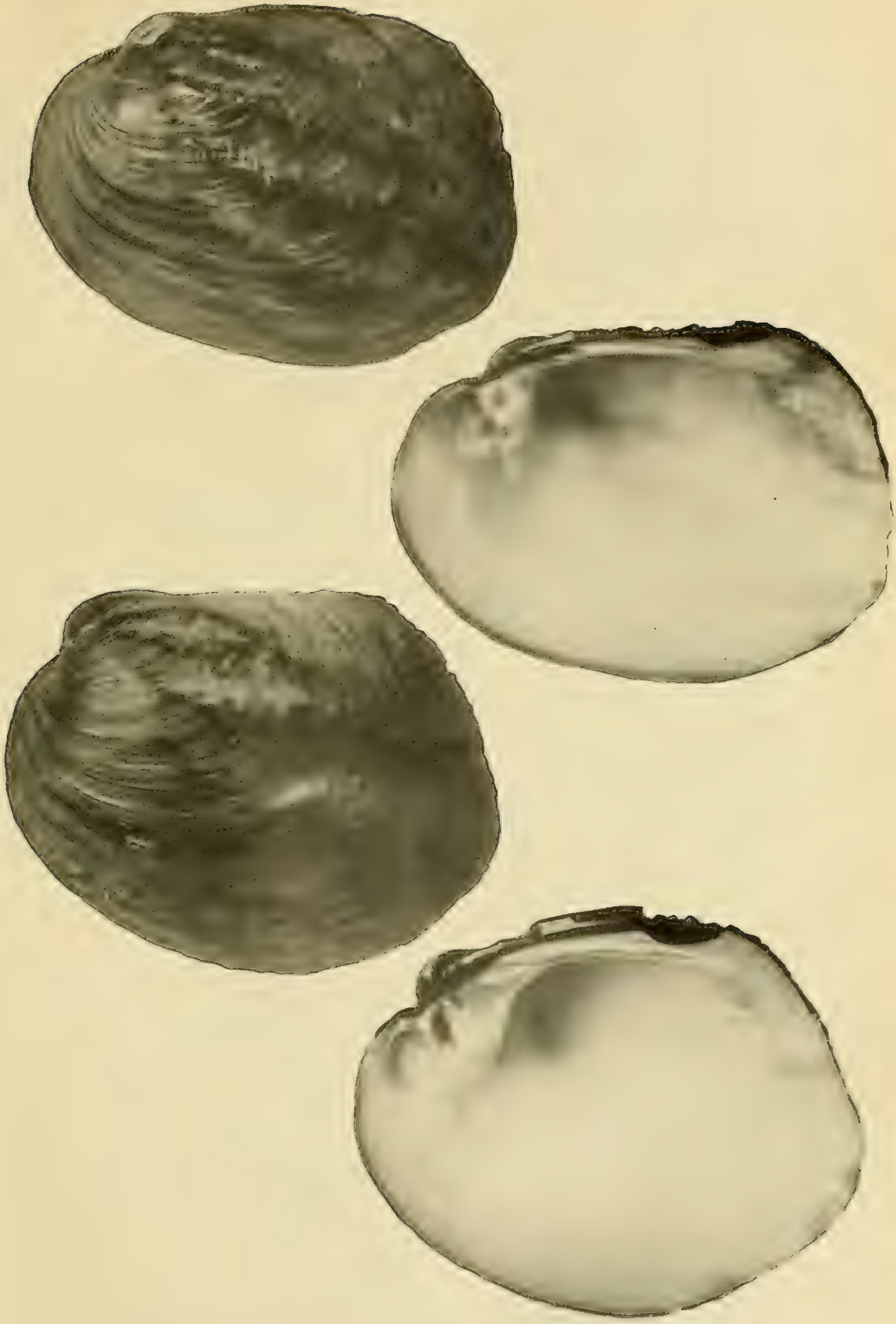
WASHBOARD GROUP.

This group comprises, practically speaking, only a single species.

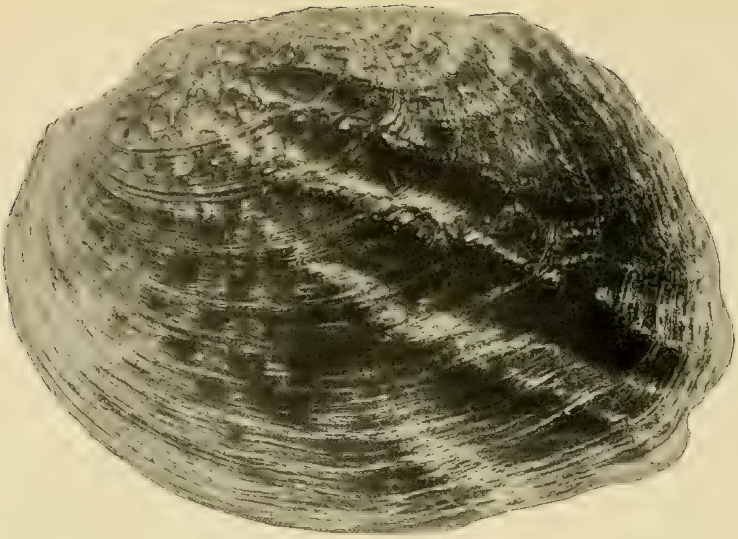
The washboard, *Quadrula heros* (Say) (Pl. XI), is the largest and heaviest species of mussel in the Mississippi Basin. One example 8 inches wide and 11 inches long and weighing over 4 pounds with the flesh, was collected by the late J. F Boepple in the Salt River, Ky. The empty shell weighed about 3½ pounds.

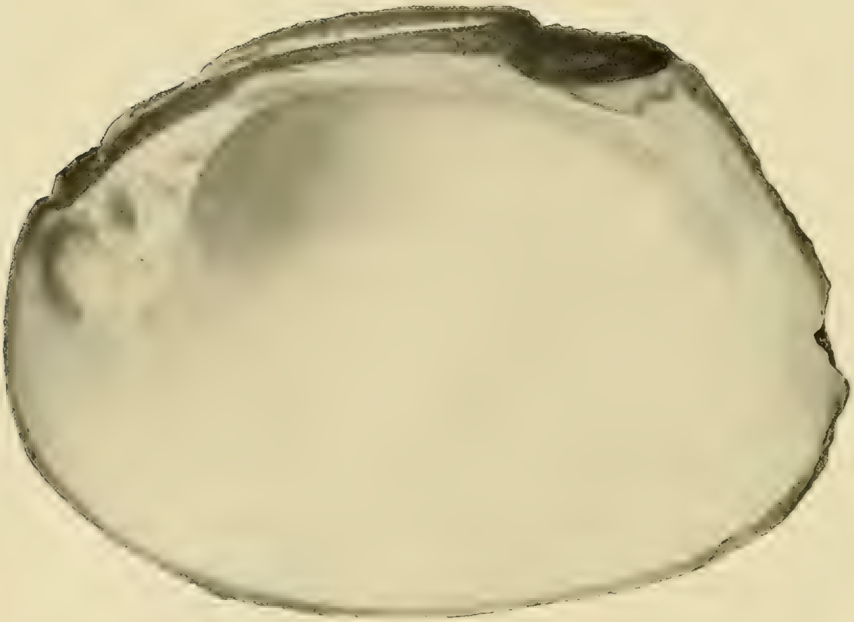
The washboard is found chiefly in large rivers in quiet, deep water and on gravel and mud bottoms.

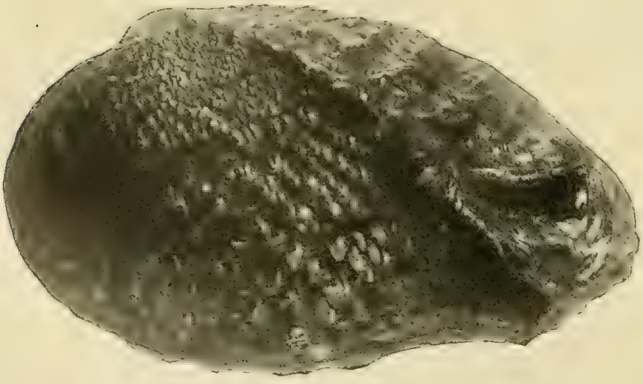
The Wabash and Illinois Rivers have the highest percentages of washboard, although there are beds in the Ohio River where this species forms nearly 50 per cent of the catch. The shell is generally of an oval outline and more or less elongated. It is valued chiefly because of its large size, making it suitable for cutting the largest-sized buttons. The material is tough and the grain uniform and regular. The iridescent part breaks easily in sawing, owing to the undulations on the back. The nacre is usually discolored with yellowish or greenish spots, and the older the shell the larger are the spots. We have received pink shells from the Illinois River. Young mussels from 3 to 4 inches long have only a few spots or none, and the iridescent part is as thick as in the older mussels, being thick enough for buttons. This part of the washboard is very similar to the



Upper pair: Three-ridge, *Quadrula undulata* (Barnes), from James River, S. Dak. (See p. 26.)
Lower pair: Blue-point, *Quadrula plicata* (Say), from Illinois River. (See p. 26.)

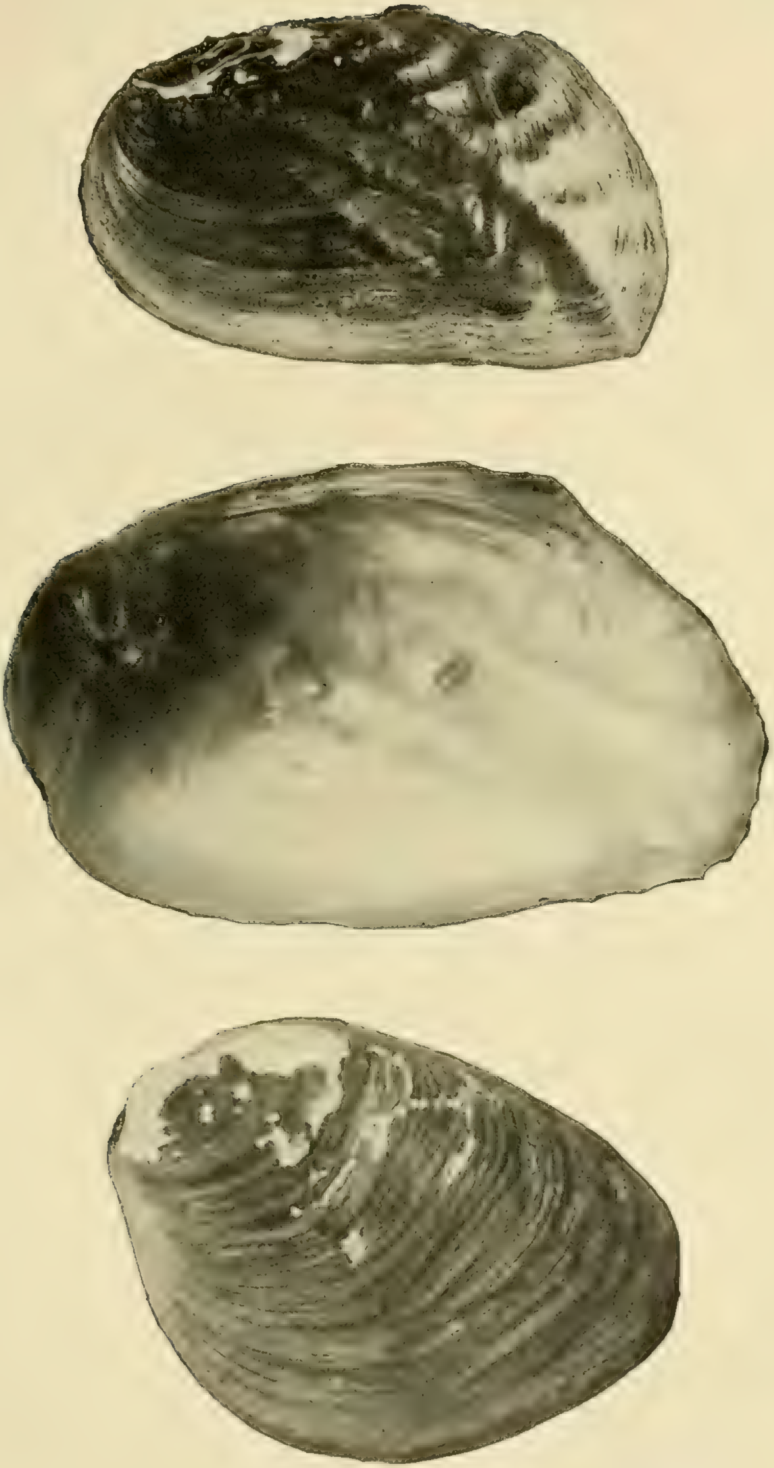






Upper and middle: Washboard, *Quadrula heros* (Say), from Mississippi River. (See p. 26.)
At bottom: Buckhorn, *Tritogonia tuberculata* (Barnes), from Mississippi River. (See p. 27.)

PLATE XII.



Upper and middle: Bank-climber, *Quadrula trapezoides* (Lea), from White River, Ark. (See p. 27.)
At bottom: Pig-toe, *Quadrula pyramidata* (Lea), from Cumberland River. (See p. 25.)

mother-of-pearl of the ocean. The washboard spawns in the late summer and early fall.

In places in Florida, Georgia, and Alabama *heros* is replaced by *Quadrula boykiniana* (Lea).

The bank-climber, *Quadrula trapezoides* (Lea) (Pl. XII), should be mentioned in this connection. It is found in streams flowing into the Gulf of Mexico, from Alabama to Texas, and northward in the Mississippi system to Tennessee and Arkansas. The shell has a deep purple nacre and is quite valueless for manufacture. Possibly it yields a proportion of pearls. It is a very familiar shell in Louisiana, Arkansas, and eastern Texas.

The buckhorn, *Tritogonia tuberculata* (Barnes) (Pl. XI), is, perhaps, better named in connection with the washboard than anywhere else. It has a naturally white nacre of good texture and quality, but is often spotted. It is thinnish at the tip and has a very rough back; some shells have a pinkish tinge. It has also been called pistol-grip, a name appropriate to the form of elongate examples. There is a short form characteristic of males and a much more elongate form common to females. It is found widely in the Mississippi and Gulf drainages and is reported as a summer breeder.

LAMPSILIS CLASS.

Such familiar and valuable shells as the mucket, the Lake Pepin mucket, and the sand shells are representatives of this class of mussels. In many respects they are quite distinct from the Quadrulas.

In commercial quality there is a wider range, not only between the species composing the class, but even within the individual species in most cases. The highest-priced shells of all are of a Lampsilis species, while some of the most worthless paper-shells are species of the same genus. Muckets may possess excellent qualities, or again they may be pink or otherwise inferior; some pocketbooks are good, some are worthless. Fat muckets from one region may sell for scarcely less than niggerheads, while those from another locality would not be looked upon with the thought of marketing. The species of Quadrula, as a rule, have more uniformity wherever found; some are better than others, but when a Quadrula is found there is a reasonable presumption that it is a shell of a certain grade, according to its species.

The primary commercial difference between Quadrula and Lampsilis is that the latter rarely shows any marked iridescence. Sometimes iridescent qualities are referred to, but this generally means merely an unusually bright luster. On the other hand, Lampsilis mussels have a more uniform thickness, and therefore yield a larger number of blanks per ton than any of the Quadrulas.

Some of these mussels are not surpassed in texture and luster, as will appear, and therefore this class of shells has been growing in favor in recent years. As previously mentioned, the raw materials first used in fresh-water button manufacture were species of Lampsilis.

The Lampsilis mussels are more rapid of growth than the Quadrulus, and they are long-term breeders. In the latter part of the summer, as a rule, the marsupial pouches are filled with eggs which develop into glochidia, and in this condition all or a large proportion of them are held over the winter. Glochidia can be found in the gills of the females at almost any season of the year. July and August, principally, constitute the intermediate season, when few glochidia can be found. These months, it is important to note, are the height of the breeding season for most of the Quadrulas.

MUCKET GROUP.

We include in this group three abundant and important shells, the mucket, the fat mucket, and the southern mucket, and three species less abundant and less readily distinguished.

The mucket, *Lampsilis ligamentina* (Lamarck) (Pls. I and XIII), is one of the most generally distributed mussels in the United States. The commercial value of the shells varies primarily with the rivers from which they are taken. The muckets of the Mississippi River have not been highly esteemed. The butt (or heavy) portion is considered too chalky, and the tips are rather thin. In many of the shells the nacre is pink in color, which greatly reduces the value. There are, however, some places in the river where the quality is superior. The muckets of the Wabash River have been considered very fine, but they are now rather scarce. The Yellow River, Ind., has produced excellent muckets. In the Ohio River better muckets are found higher up the river. Mr. Boepple reported them abundant and of good quality at Marietta, Ohio. They are abundant in the Green River, Ky., and are of excellent quality in the Little Barren River, Ky. Mr. Boepple also stated that he had found muckets which approached marine shell in luster in the Cottonwood River, Kans. Muckets are comparatively scarce in the Illinois River, but some of the fishermen believe they are becoming more numerous.

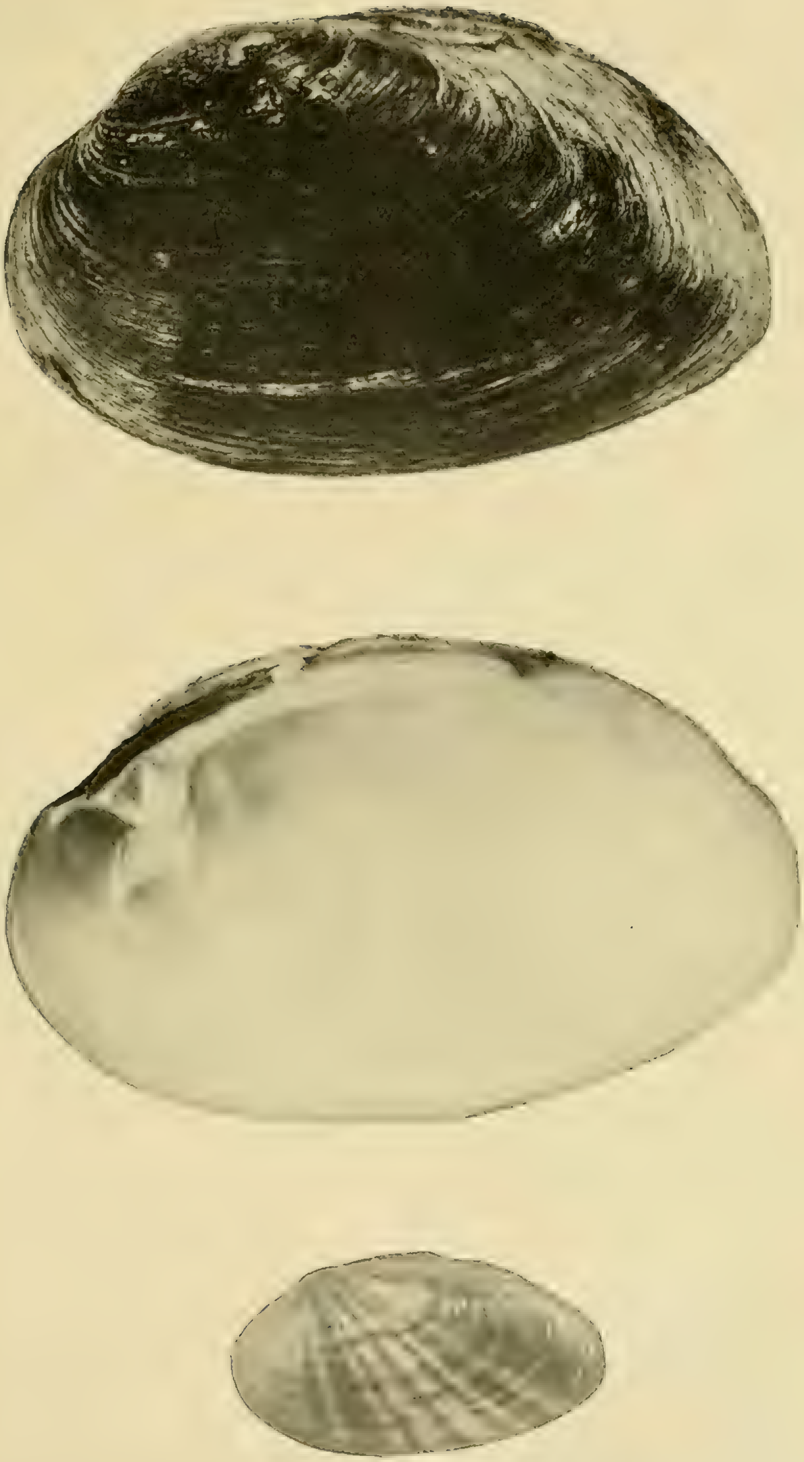
The mucket can be found in almost any sort of stream, and the best shells are usually found where there is a good current, but this is not a universal rule. In the Grand River, Mich., where the current is good, the muckets have an excellent luster, but too large a proportion of the shell is very thin.

The material works up well; it is soft and has a straight grain, although in old shells the nacre splits, and the nearer to the hinge one is cutting the worse this trouble becomes. Some muckets have excellent luster and clear color, but these qualities vary with the locality. The color varies even in the same bed; pink muckets and white muckets are found side by side, and the cause of this difference in color is as yet unexplained. The values on the basis of ton price in 1914 and 1919, respectively, may be stated as approximately $17 and $45.

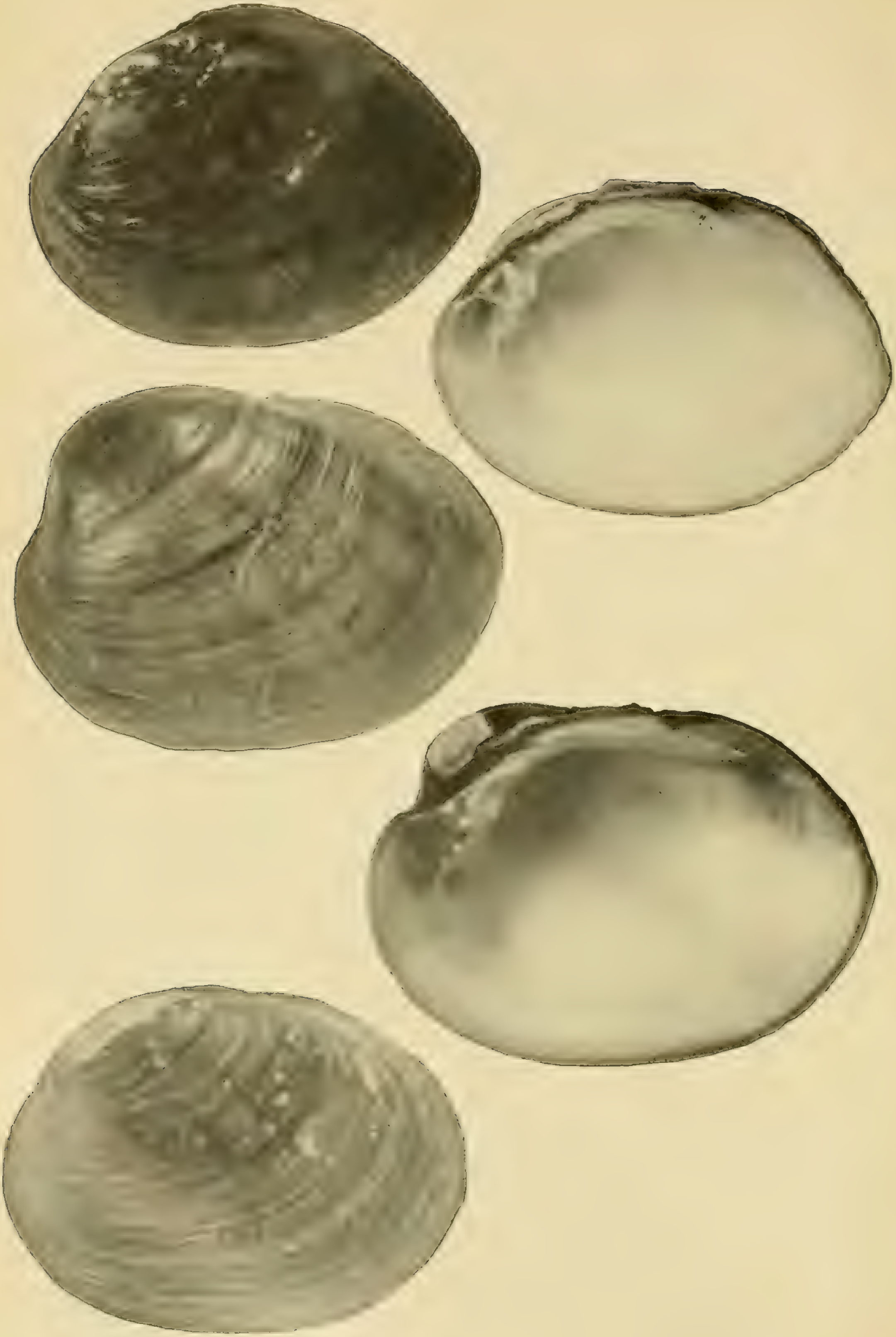
The mucket may, perhaps, liberate its glochidia to some extent in the fall, but principally in spring and early summer. It has a relatively wide range of fish hosts, principally among the game fishes.

The little rainbow-shell, *Lampsilis iris* (Lea) (Pl. XIII), with its bright-green, broken rays on a yellowish shell, is often mistaken for a young mucket. It is found in the Ohio River system, and also in the streams of Illinois, Wisconsin, Michigan, and eastward.

The southern mucket or yellow-back mucket, *Lampsilis ligamentina gibba* Simpson (Pl. XIV), one of the finest of all shells, differs from the common mucket in being shorter and more compressed. The shell is therefore flatter and the thickness more even; the texture and luster are unsurpassed, and the material works easily and economically. This form is found in streams south of the Ohio River and perhaps, too, in that



Upper and middle: Mucket, *Lampsilis ligamentina* (Lamarck). (See p. 28.)
At bottom: Rainbow-shell, *Lampsilis iris* (Lea), from Tippecanoe River, Ind. (See p.



Upper pair: Southern mucket, *Lampsilis ligamentina gibba* Simpson, from Black River, Ark. (See p. 28.)
Middle pair: Higgin's eye, *Lampsilis higginsii* (Lea), from Mississippi River. (See p. 29.)
At bottom: *Lampsilis orbiculata* (Hildreth), from Cumberland River. (See p. 29.)

river. Our collections have been principally from the Cumberland, Clinch, and Holston Rivers.

The Higgin's eye, *Lampsilis higginsii* (Lea) (Pl. XIV) [a] is a rather uncommon species, but a few may be found in almost any carload of mixed shells from the Ohio or Illinois Rivers, or from the middle section of the Mississippi River. The nacre is often yellowish or pinkish, but white shells are of first grade, with good thickness and luster.

Lampsilis orbiculata (Hildreth) (Pl. XIV) very closely resembles *Lampsilis higginsii*, but is more southern in its distribution. Its qualities are about the same as those of the preceding species.

The fat mucket or Lake Pepin mucket, *Lampsilis luteola* (Lamarck) (Pls. I, XV and XVI), would not have been classed some years ago as an important commercial shell. Now, since the Lake Pepin form has come into use, the species is considered one of the best. It is widely distributed over the upper half of the Mississippi Basin, the Great Lakes drainage, and, according to Simpson, the entire Dominion of Canada east of the Rocky Mountains. Its occurrence as an economic form is quite restricted. The fat mucket is rarely found in rapidly moving water but is adapted to slow or still water. It is the principal shell of the lakes of the Middle West, both in the Mississippi and the Great Lakes drainage, but such waters are not generally suited to the production of commercial shell. The fat muckets of the lakes are usually somewhat dwarfed and inflated, with the shell strongly curved, and too thin to produce more than one or two small blanks, if any. In some cases they might be confused with dwarfed pocketbooks. The species is also found in rivers and creeks, but usually close along shore, perhaps well up on the banks and out of the main current. Examples from such locations generally have an inflated but more elongate form, the forward part (or, in commercial terms, the butt) of the shell being thick enough for blanks, while from one-third to one-half of the shell, or more, is so thin as to produce only tips at best. In this form the fat mucket is sometimes much like the slough sand-shell in superficial appearance. Such shells can be used, but they are not always valued highly.

Within recent years the beds of Lakes Pepin and St. Croix have been discovered commercially. These lakes yield a very distinct type of fat mucket, which is remarkably even in thickness, with a surface relatively flat in males, and even in females much less curved than usual. Practically the entire surface can be cut into blanks which are of a suitable thickness. No other shell of any species cuts with so little waste, either as to the proportionate weight of shell that is thrown away after cutting out the blanks or as to the small amount to be ground from the blanks in reducing them to a proper thickness for buttons. The shell is clear white, the texture good, and the luster leaves nothing to be desired. The Lake Pepin mucket brought in 1914 and 1919, respectively, about $20 and $35 per ton.

In the brilliancy and the extent of the iridescent portion the Lake Pepin mucket is not quite equal to the niggerhead and pimple-back, but a measure of iridescence is found, and in pearly character of the nacre it is fully equal to any other. As regards economy, it has been found that 14 or 15 pounds of blanks are a very good return from 100 pounds of niggerhead shells, while more than 20 pounds of blanks may be obtained from 100 pounds of Lake Pepin muckets. This shell is, therefore, the nearest approach to an ideal button shell now found among fresh-water mussels.

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[a] This species and the following may be more closely related to the pocketbook than to the mucket, as Ortmann holds for *orbiculata*. Our classification is only for shell qualities, of course.

The rate of growth is relatively rapid. At the Fairport station mussels of this species have grown to a length of more than 1 inch within six months after the date of infection upon the fish. These were in floating crates in the river. The age of commercial shells can not yet be positively stated but it is probably from 4 to 6 years.[a] Like most others of the genus, it is a long-term breeder. Its fish hosts are the common game fishes, such as the basses, crappies, sunfishes, perches, and sand pikes. Some have been grown in ponds at the Fairport station to a length of about 1 inch in a season, and very thin buttons have been cut from such shells at the end of the second growing season. The Lake Pepin mucket lends itself to methods of artificial propagation better than any other species.

Lampsilis hydiana (Lea) may be called the southern fat mucket, being found in the lower portion of the Mississippi Basin. The specimens we have had might easily be confused with the Lake Pepin form and appear to resemble it in qualities of shell. It occurs in Louisiana, Texas, Arkansas, and neighboring States.

The butterfly, *Plagiola securis* (Lea) (Pl. XV), presents another case of a mussel which must be placed far from its systematic position. Its shell qualities place it more nearly with the muckets than with any others. It is a well-known mussel of the larger streams of the Mississippi and Ohio drainages and is reported from Alabama. Its beautiful form and markings give it the name of butterfly. Mr. Boepple remarked that comparatively few females were found, and that they are of much lower commercial value than the males, on account of being so much thicker and lacking in luster.

The shells of the males are very flat and have a white color and good luster, with a rather uniform thickness over most of the shell. There are few places where 100 pounds can be obtained, but they are often met with in mixed shipments, and are valued.

It is a long-term breeder, and its most common fish host is the fresh-water drum, or sheepshead, *Aplodinotus grunniens*.

A smaller species, the deer-toe, *Plagiola elegans* (Lea), is very common, but rarely attains a size sufficient for cutting blanks.

POCKETBOOK GROUP.

The pocketbook, *Lampsilis ventricosa* (Barnes) (Pls. XV and XVI), is a large and very inflated mussel found throughout the Mississippi and Great Lakes drainages (as well as in the Nelson River), in large and small rivers, and in some lakes. It is one of the species most familiar to the fishermen and most readily obtained. It is found in gravel bars or sandy bottom, sometimes alongshore and sometimes in the deeper water.

The commercial value of the pocketbook is generally rather low. The shells of the male are better than those of the female. There are some rivers in which the pocketbook becomes a very good shell for button manufacture. Mr. Boepple had an example from the Yellow River of Indiana, from one side of which 52 18-line blanks were obtained, all of which would make good buttons. The Yellow River specimens are among the best, since the hinder or tip portion of the shell is thick enough for buttons. As a rule better shells are found in small rivers and creeks than in the large rivers.

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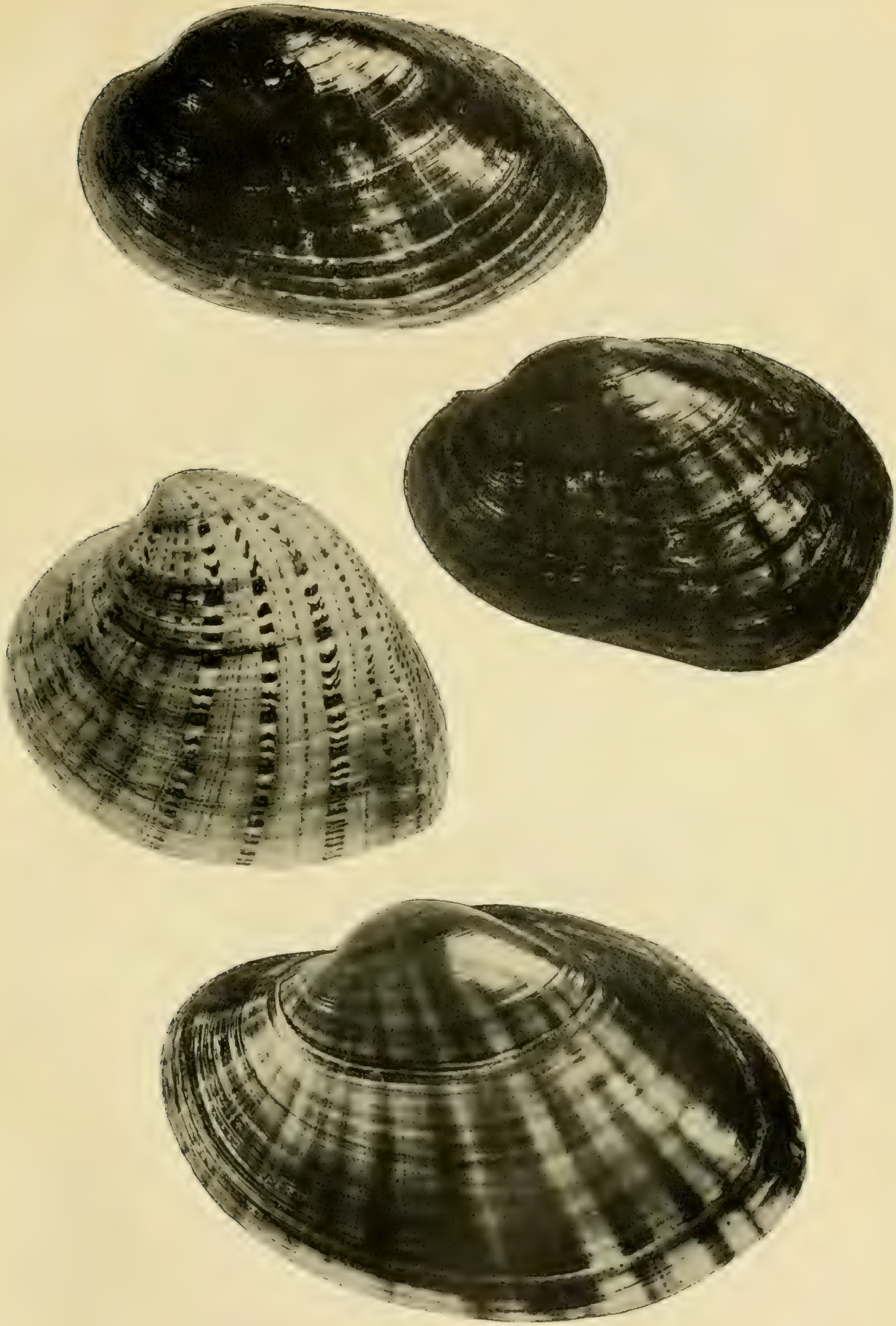
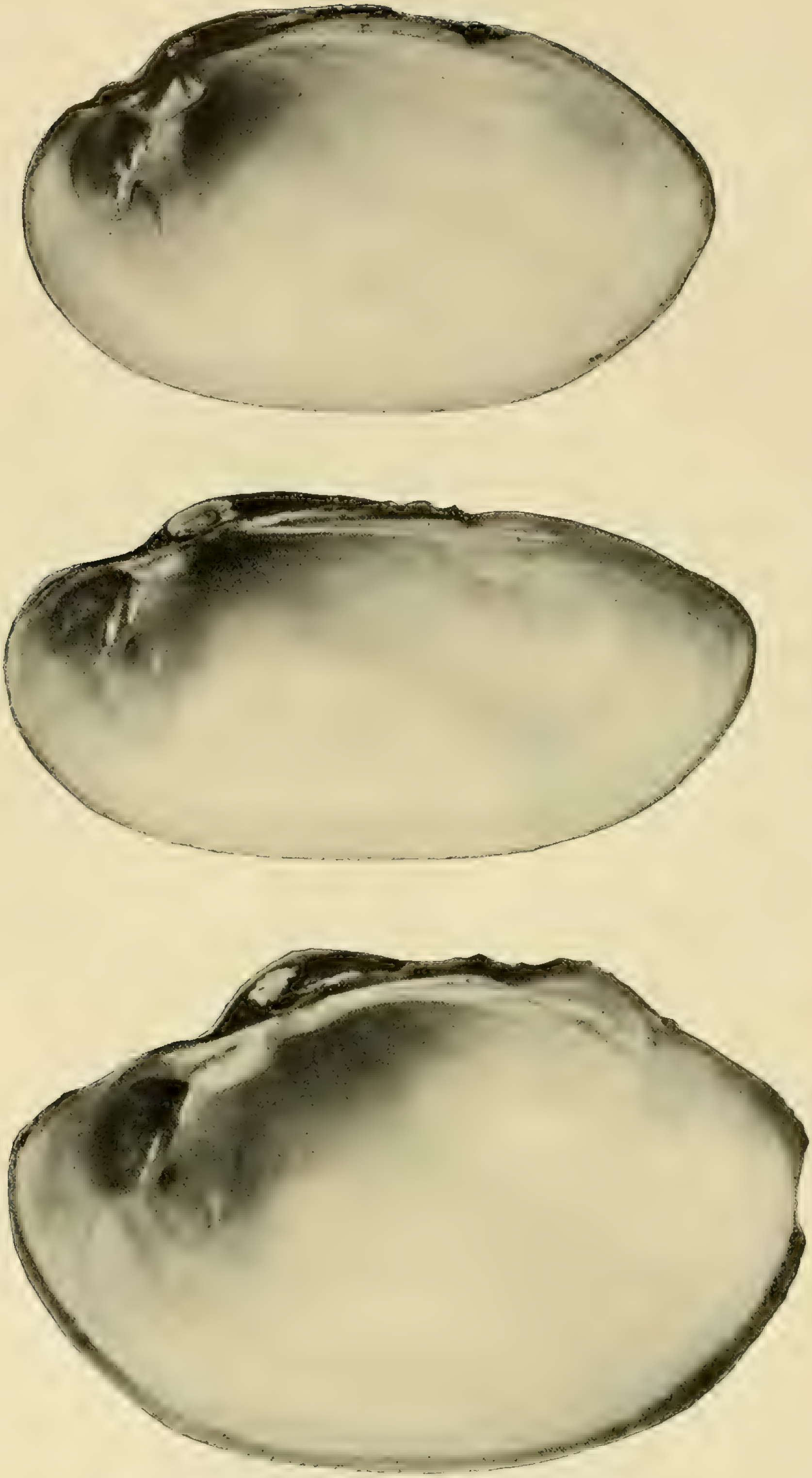
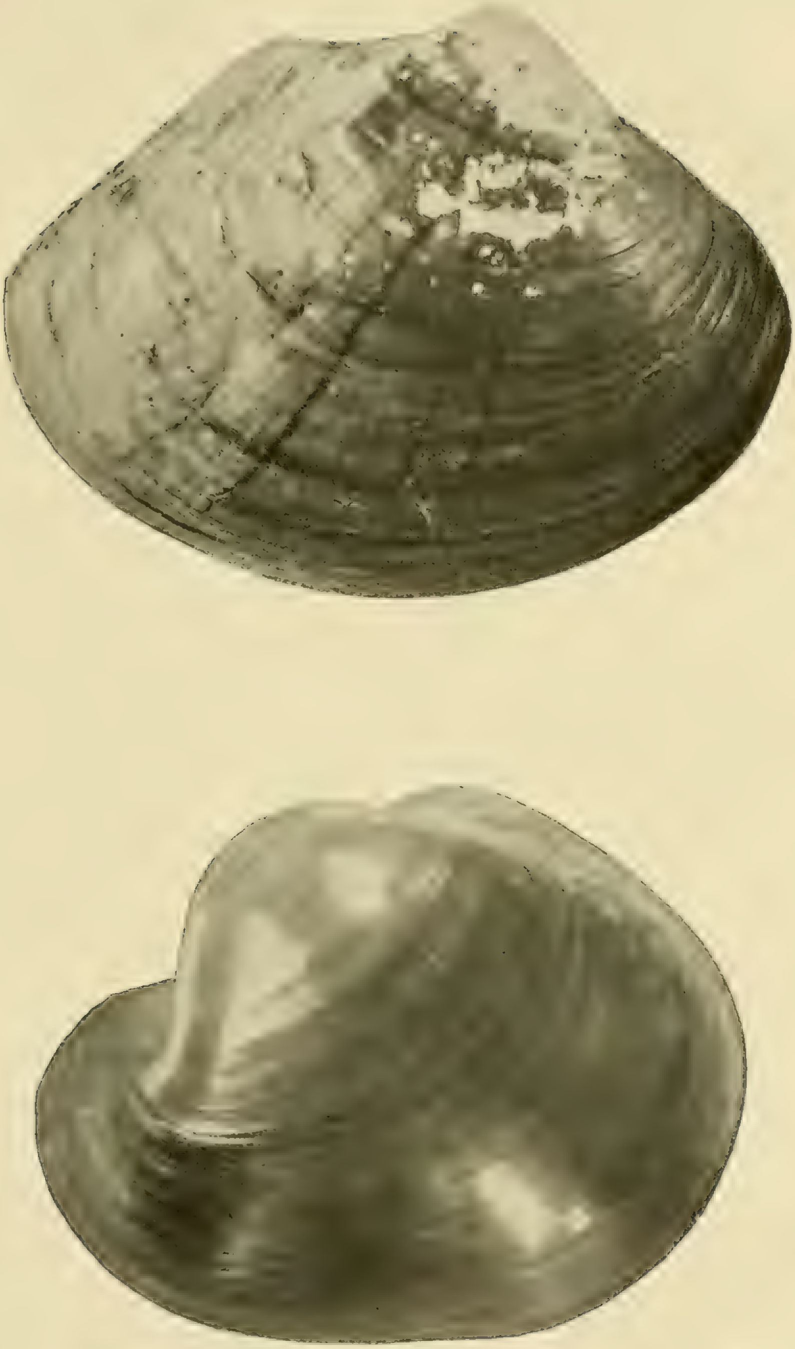
[a] At ages of 3½ and 4½ years some Lake Pepin muckets reared in a pond at the Fairport station yielded 12 to 22 14-line blanks over 2½ lines in thickness.



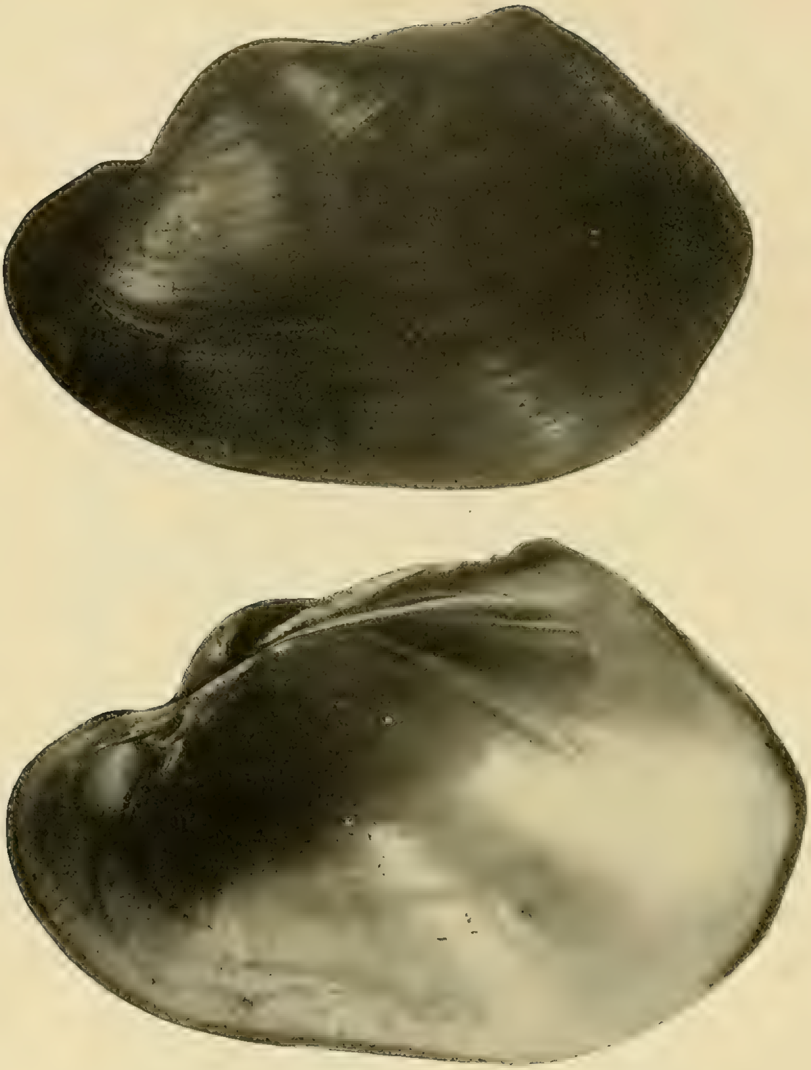
Upper left: Lake Pepin mucket, *Lampsilis luteola* (Lamarck), male. (See p. 29.)
Upper right: Lake Pepin mucket, *Lampsilis luteola* (Lamarck), female. (See p. 29.)
Lower left: Butterfly, *Plagiola securis* (Lea). (See p. 30.)
Lower right: Pocketbook, *Lampsilis ventricosa* (Barnes). (See p. 30.)

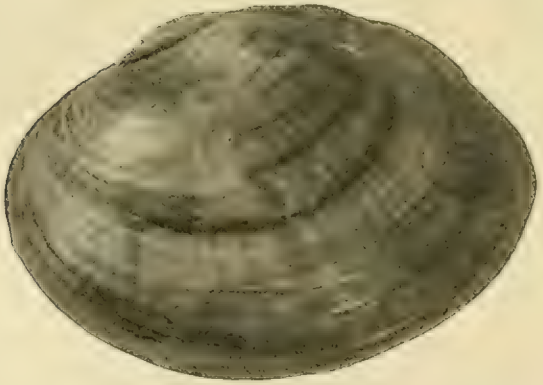


Upper: Lake Pepin mucket, *Lampsilis luteola* (Lamarck). (See p. 29.)
Middle: Yellow sand-shell, *Lampsilis anodontoides* (Lea). (See p. 31.)
Lower: Pocketbook, *Lampsilis ventricosa* (Barnes). (See p. 30.)



Upper: Grandma, *Lampsilis ovata* (Say), from Cumberland River. (See p. 31.)
Lower: Pocketbook, *Lampsilis capax* (Green), from Mississippi River. (See p. 31.)





Upper pair: Purply, *Lampsilis purpurata* (Lamarck), from Kiamichi River, Okla. (See p. [illegible]
At bottom: *Lampsilis multiradiata* (Lea), from Stone River, Tenn. (See p. 31.)

Often the forward or butt part of the shell is somewhat chalky and comprises scarcely more than one-fourth of the shell surface, while the remaining three-fourths is too thin and brittle. A noteworthy feature of the shell is the lateral hinge, which has a beautiful pearly luster. The cardinal teeth, too, have an attractive form and are used in the manufacture of cheap jewelry.

Lampsilis ovata (Say) (Pl. XVII), the southern pocketbook or grandma, is not ordinarily distinguished from *ventricosa*. It is found in the Ohio River and tributaries, as in the Clinch, Holston, and Cumberland Rivers. It is rather thinner and inferior to the common northern pocketbook.

Lampsilis (*Proptera*) *capax* (Green) (Pl. XVII), also called pocketbook and confused with the others, is not closely related to them in spite of its superficial resemblance. It is quite too thin for value in button manufacture. The purply *Lampsilis* (*Proptera*) *purpurata* (Lamarck) (Pl. XVIII) is probably related to *capax*. It is very familiar to shellers in Texas, Louisiana and Arkansas, but the thinness of the shell, as well as the deep purple nacre, makes it unfit for the trade. It is one of the most beautiful shells.

Another species which looks something like a young pocketbook, but which never attains so large a size, is *Lampsilis multiradiata* (Lea) (Pl. XVIII) of the Ohio drainage and southern Michigan. Its shining greenish-yellow, bright-rayed shell is very attractive to the eye.

SAND-SHELL GROUP.

There are three sand-shells, the yellow, the slough, and the black.

The yellow sand-shell, *Lampsilis anodontoides* (Lea) (Pls. I, XVI and XIX), is the most highly prized of all commercial shells. It is never very abundant, but it is probably the most widely distributed of all the species discussed. Its distribution as given by Simpson is: "Entire Mississippi drainage, except, probably, the upper Missouri. All the Gulf drainage from the Withlacoochee River, Fla., to the Rio Grande, and into Mexico." The common name is derived from the clear yellow or brownish-yellow exterior color.

These shells are too valuable for use in button manufacture; consequently they are always sorted out. Many tons of them are bought from the fishermen on the rivers to be used for export. Even those that reach the factories in mixed cars are sorted out in the yard to be sold again to shell jobbers. In very recent years, however, due to war conditions, many sand-shells have been cut into buttons in domestic manufacture. Some years ago it was said that the sand-shells were shipped chiefly to France; in the few years preceding 1914 the greater part seemed to have been destined for the German market, and the price on the rivers in 1913 was $60 per ton. The export was necessarily interrupted in 1914, but in the early part of 1911 the writer was informed of an offer of $92.50 per ton f. o. b. New York, and a consular report from Hamburg quoted these shells at prices equivalent to from $108 to $151 per long ton, when niggerheads were quoted in the same market at $54, and muckets at from $47 to $119. About three pairs of sand-shells (the shells from three mussels) usually make a pound, so that the mussels were worth at least 1 cent apiece on the river and, at the date of the consular report, 2 cents apiece or more in Hamburg. In 1919, with some export demand, yellow sand-shells bring about $90 per ton.

The shell owes its value to the following characteristics: (1) Its luster and pearly qualities are almost if not quite equal to the marine shells; (2) its texture is smooth and firm; (3) the shape of the shell is long and straight, so that pieces suitable for knife handles or other novelty objects can easily be cut from it; and (4) the comparative uniformity of thickness and the light hinge make the shell yield the best return in proportion to its weight.

This species is found in small quantity mixed with other mussels in the principal mussel beds or on the more sandy or gravelly shoals. It seems also to live well in muddy bottoms.

Like others of the genus, it is a long-term breeder, but is, so far as known, very restricted in parasitism. No other hosts than the several species of gars seem to carry it well, but there is reason to believe that the large-mouth black bass may also serve as host. It is a peculiar fact that the two species of most restricted parasitism are the niggerhead and the yellow sand-shell. We know only one host for the niggerhead, yet it is a very abundant mussel; there are several species of gars, and they are quite plentiful; but the sand-shell is never very numerous in any locality.

A noticeable characteristic of the yellow sand-shells is the habit of wandering about on the bottom; for they travel more than the mussels of any other species. The yellow sand-shells are frequently observed to crawl up on the shoals with the rising water, and it is common report that after the subsidence of floods they may sometimes be found far out in the swamps.

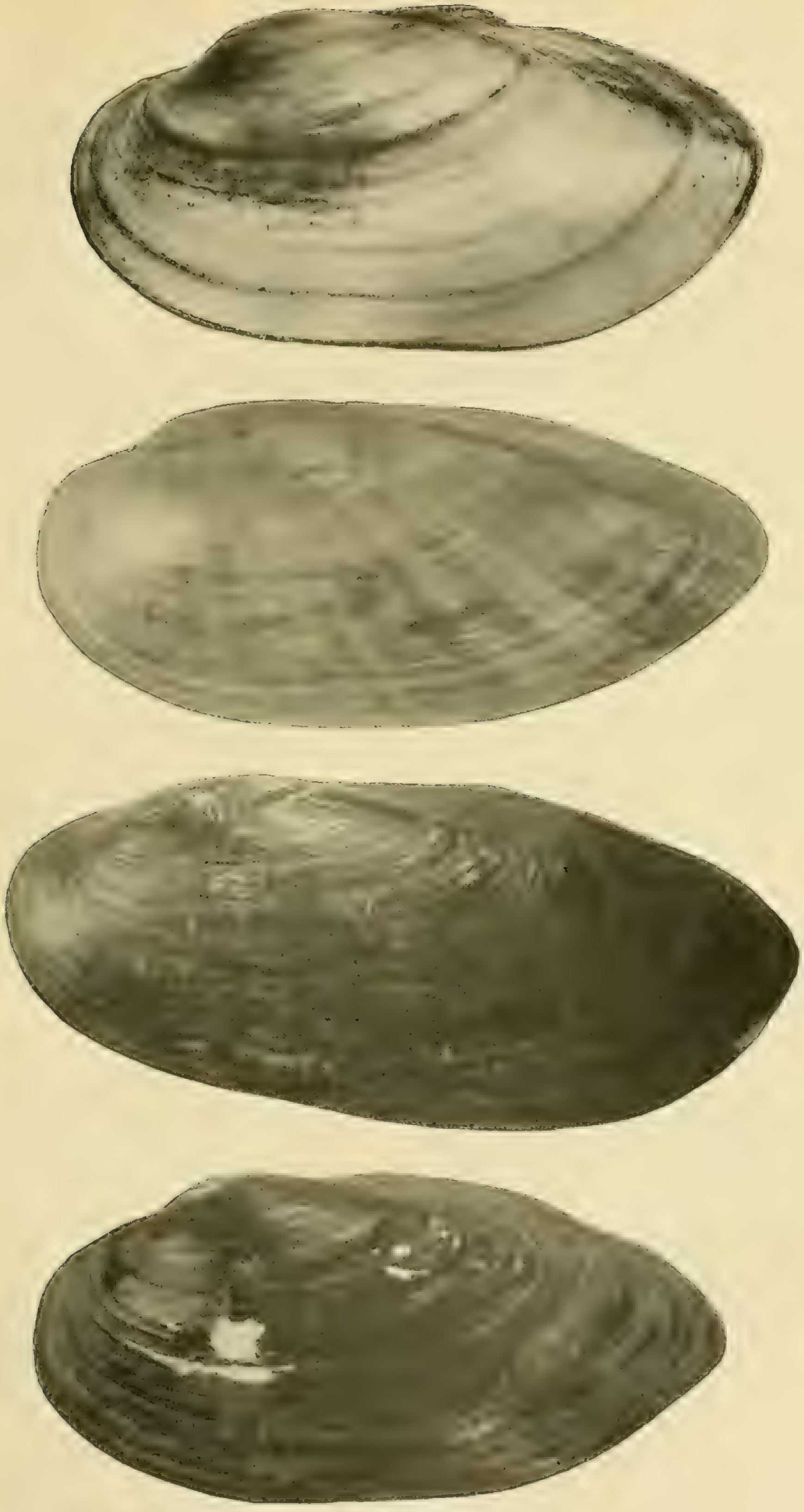
The sand-shell has a relatively rapid rate of growth, probably attaining a market size in four to six years. Its growth is undoubtedly more rapid in the South, as in Arkansas, than in the North. If any species should prove adapted for commercial rearing in private waters, it would seem that the yellow sand-shell and the Lake Pepin mucket offer the best promise.

The slough sand-shell, *Lampsilis fallaciosa* (Smith) Simpson (Pl. XIX), is similar to the yellow sand-shell but is generally smaller and rather too thin. Its geographic range is wide, and it is said to have been much more abundant formerly than now. There are few places in which the slough sand-shell is at all numerous. It is common in the lower part of the Illinois River, and is a very familiar shell in the Wabash River, where it is mistakenly called bank-climber.

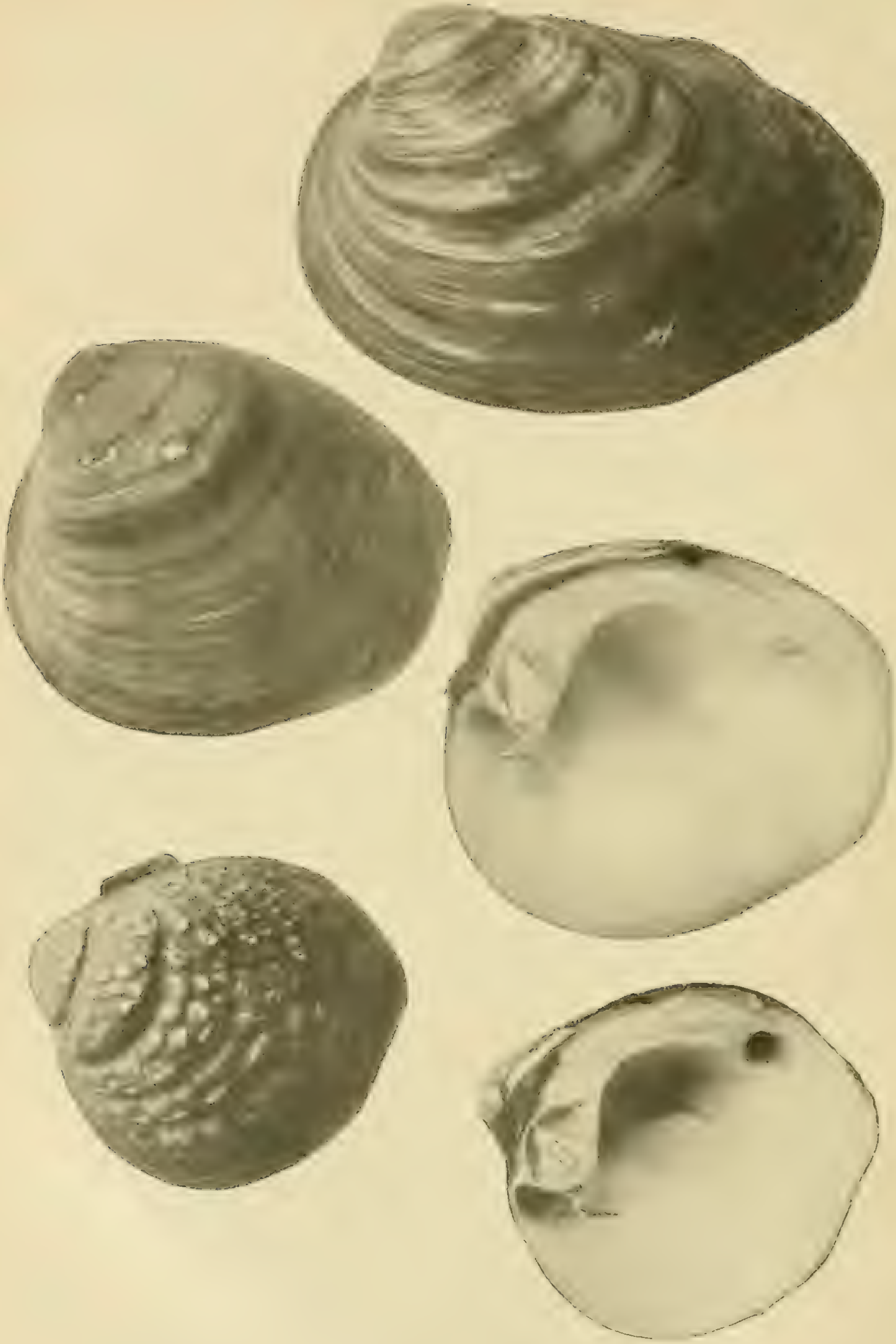
The black sand-shell, *Lampsilis recta* (Lamarck) (Pl. XIX), is also widely distributed in the Mississippi River and the Alabama River drainages, the Red River of the North, and the St. Lawrence system. It is found principally in the upper part of the Mississippi Basin.

The shell is generally more compressed and heavier than the other sand-shells. The nacre has an excellent surface, but its economic qualities are variable. Often the nacre is deeply colored, pink, salmon, or purplish. White shells are the rule in the Mississippi and in some other streams, and many of them are of very superior quality. They were sometimes exported with the yellow sand-shell. The black sand-shell has a peculiarly good luster and pearliness and even iridescence; some of the most beautiful specimens the author has seen were, however, condemned by manufacturers as too brittle and as otherwise inferior.

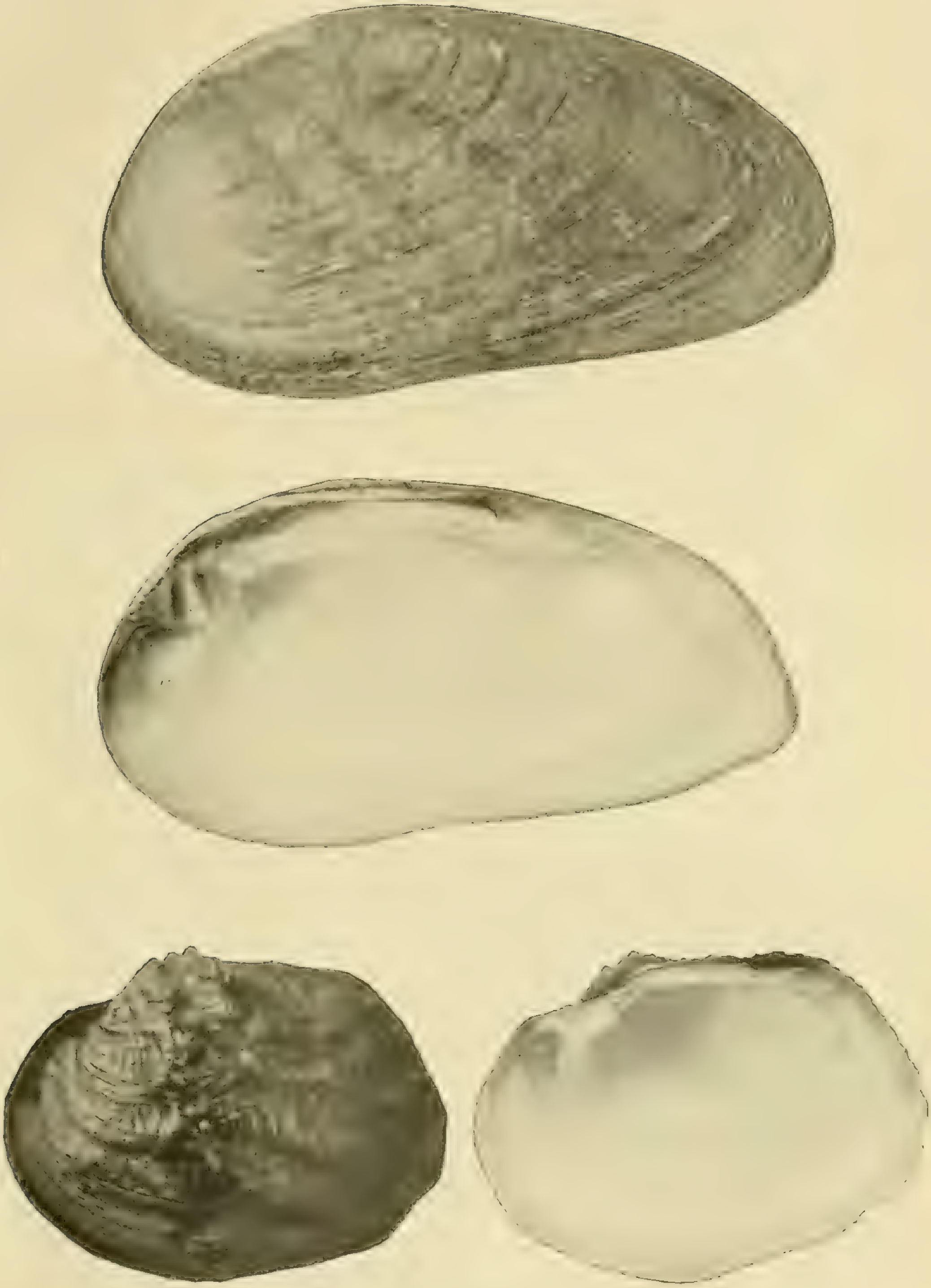
Lampsilis subrostrata (Say) (Pl. XIX) might sometimes be confused with the black sand-shell or more easily, perhaps, with very dark-colored slough sand-shells. It is entirely too thin to be of value.



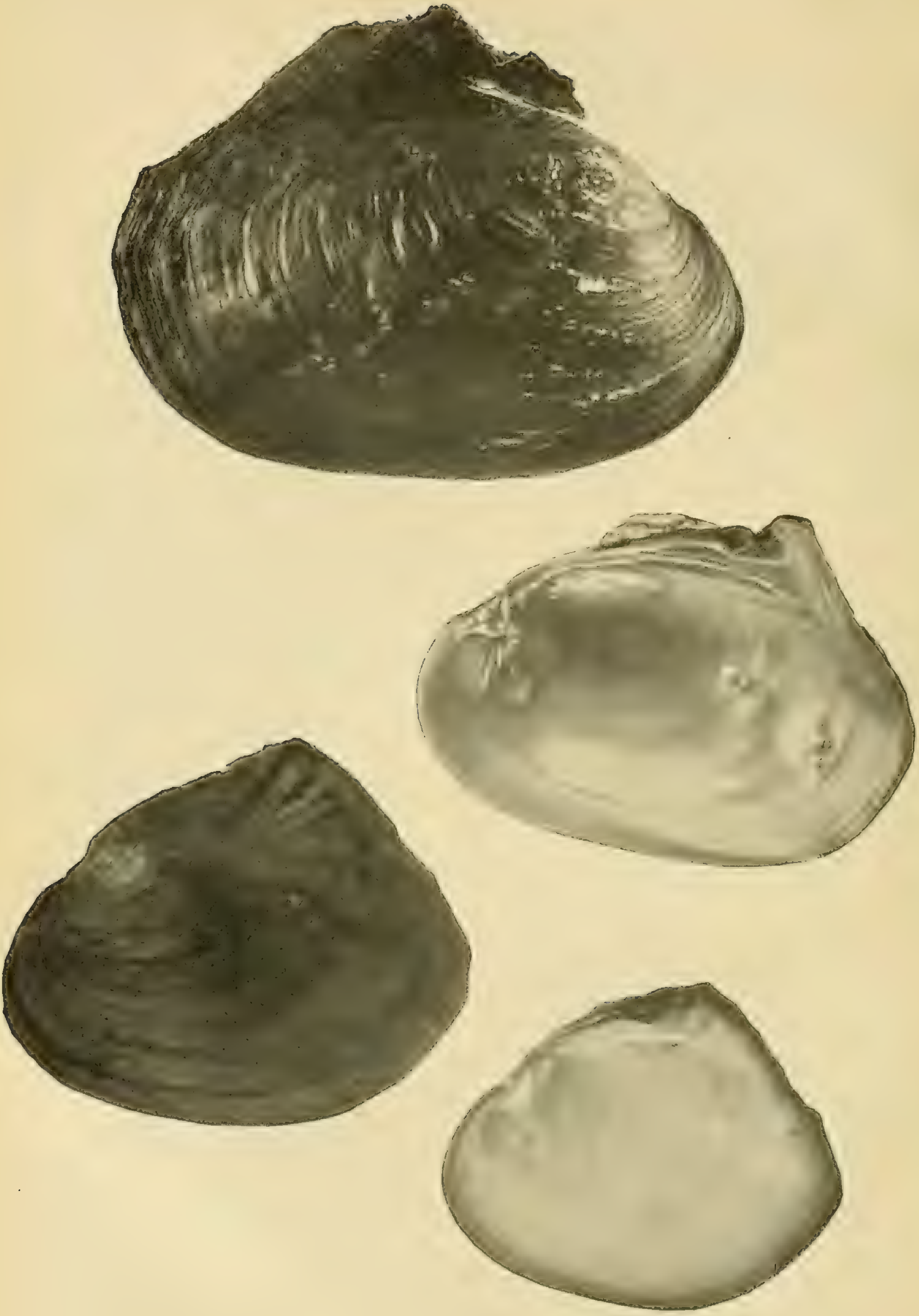
Yellow sand-shell, *Lampsilis anodontoides* (Lea), from Mississippi River. (See p. 31.)
Slough sand-shell, *Lampsilis fallaciosa* (Smith) Simpson, from Mississippi River. (See p. 32.)
Black sand-shell, *Lampsilis recta* (Lamarck), from Mississippi River. (See p. 32.)
——— ———, *Lampsilis subrostrata* (Say), from Mississippi River. (See p. 32.)



Top: Bullhead, *Pleurobema aesopus* (Green), from Wabash River. (See p. 33.)
Middle pair: Dromedary mussel, *Dromus dromas* (Lea), from Cumberland River. (See p. 33.)
Lower pair: Fan-shell, *Cyprogenia irrorata* (Lea), from Cumberland River. (See p. 33.)



Upper pair: Kidney-shell, *Ptychobranchus phaseolus* (Hildreth), from Obey River, Ky. (See p. 33.)
Lower pair: Rock pocketbook, *Arcidens confragosus* (Say), from Mississippi River. (See p. 34.)



Upper left and middle right: Pink heel-splitter, *Lampsilis alata* (Say), from Mississippi River. (See p. 33.)
Lower left and lower right: White heel-splitter, *Symphynota complanata* (Barnes), from Kankakee River. (See p. 34.)

MISCELLANEOUS GROUPS.

There remain for brief mention about a dozen species which have little in common. None is very numerous, generally speaking, but all are more or less familiar to fishermen and manufacturers, while nearly all enter to some extent into button manufacture, although they are rarely bought intentionally. Some, at least, have certain good qualities.

BULLHEAD GROUP.

The bullhead, *Pleurobema æsopus* (Green) (Pl. XX), is a yellow-back, thick, knobby shell, with nacre of excellent whiteness and luster. It is, however, exceedingly hard in texture, difficult, therefore, to cut, and injurious to the saws. After the blank is cut, the button is finished readily and takes a good polish. The fishermen in some localities have facetiously dubbed this shell the "clear profit," because it can be thrown in to add weight at a profit to themselves and, supposedly, at a loss to the buyer. Sheep-nose is another name, referring to its form. It is a mussel of rather wide distribution in the Ohio drainage and eastern part of the Mississippi Basin northward.

The fan-shell, or ringed warty-back, *Cyprogenia irrorata* (Lea) (Pl. XX), is a smaller and flatter mussel of good form and appearance, but its qualities are reported to be similar to those of the bullhead. It occurs in the Ohio drainage, especially Tennessee and Kentucky.

The dromedary mussel, *Dromus dromas* (Lea) (Pl. XX), is somewhat like the fan-shell, but without the low protuberances on the back of that shell. It is found in the Tennessee and Cumberland River systems. In appearance it suggests the southern mucket, but its qualities, so far as known, correspond to those of the fan-shell.

The kidney-shell, *Ptychobranchus phaseolus* (Hildreth) (Pl. XXI), is a much more elongate shell, with hard nacre and an undesirable steely luster. It is found in the Ohio drainage and is reported to extend northward to Michigan and southwestward to Louisiana, Arkansas, and Kansas.

HEEL-SPLITTER GROUP.

The white heel-splitter, or pancake, *Symphynota complanata* (Barnes) (Pl. XXII), is of wide distribution in the upper Mississippi and Ohio drainages, the upper St. Lawrence drainage, and the Mackenzie River. It has a large, fine surface, but unfortunately, the shell is nearly always thin. In some localities it becomes very large and of suitable thickness but is brittle. The buttons can be finished with good luster, but the shell is liable to split into pieces when the blanks are being cut. It is said that they can be cut readily when fresh from the river and before the shell has so dried out as to be checking and splitting.

In some places the name elephant's ear is applied to this species. The name is appropriate enough, except that it has already been so generally applied to another species to be discussed later.

The fluted shell, *Symphynota costata* (Rafinesque), a comparatively thin-shelled mussel of wide distribution, has recently come into use from certain streams in Wisconsin.

The pink heel-splitter, *Lampsilis alata* (Say) (Pl. XXII), is mentioned in this connection only because of the confusion of names. It has about the shape and thickness of the white heel-splitter but is always purple or pink and is worthless for button manufacture. The beauty of the nacre and of the teeth makes it useful in novelty work. It occurs in the Mississippi drainage at least as far south as Arkansas, as well as in the drainages of the St. Lawrence River and the Red River of the North.

The rock-pocketbook, or bastard shell, *Arcidens confragosus* (Say) (Pl. XXI), has little resemblance to the white heel-splitter in form, but its nacre seems to be of the same character. It has the rough exterior of a blue-point, with the inflation of a pocketbook, which accounts for its common names. It is probably related to the Symphynotas. The species is rare but widely distributed.

ELEPHANT'S-EAR GROUP.

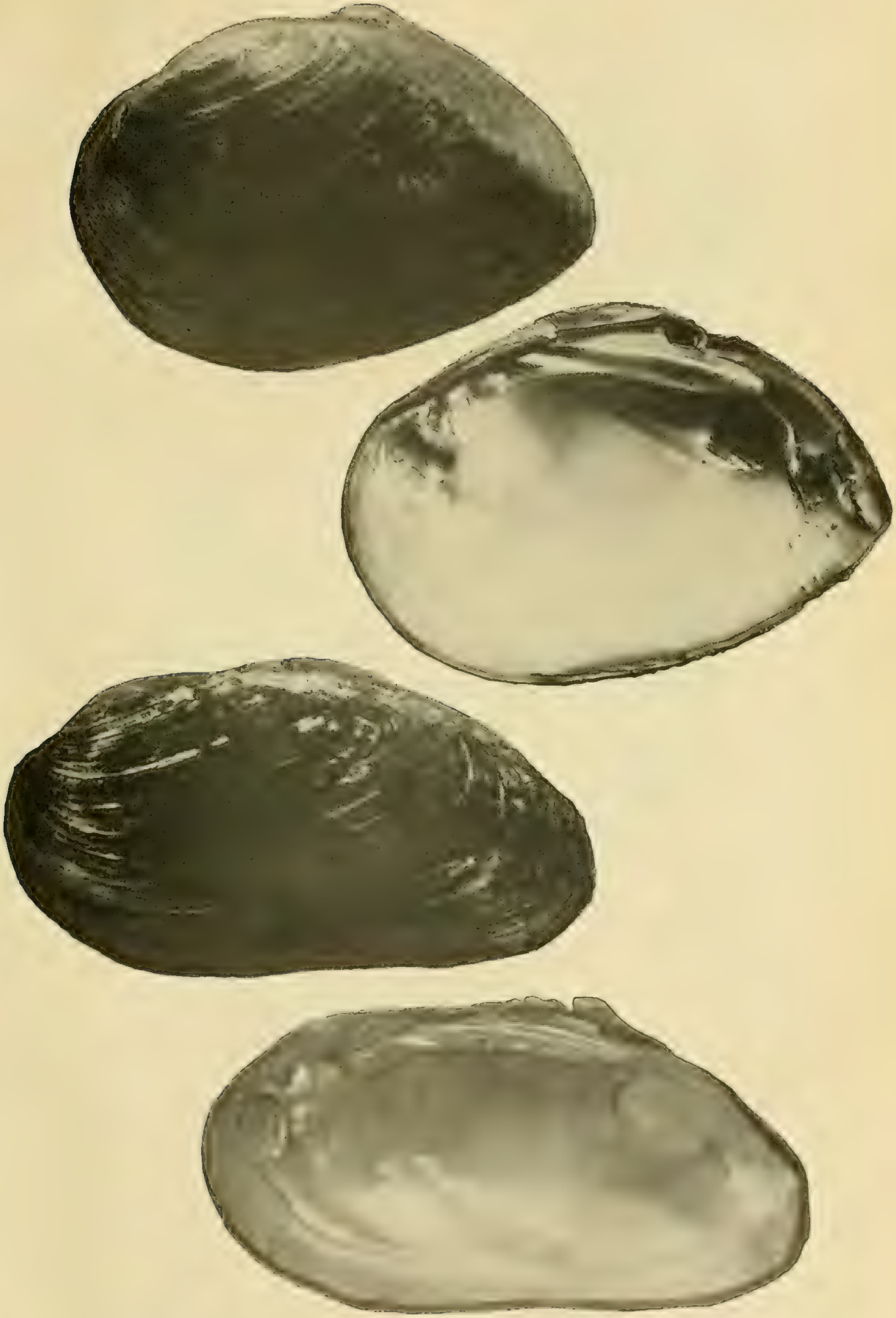
This is the last group of commercial mussels, and the shells possess peculiar features, good and bad. There are only two species to be considered, the elephant's ear, *Unio crassidens* (Lamarck) (Pl. XXIII), and the spike or lady-finger, *Unio gibbosus* (Barnes) (Pl. XXIII). The former is distributed through the Mississippi drainage generally, and occurs also in the Alabama, Tombigbee, and Chattahoochee Rivers. The spike has a very similar distribution, but extends into the St. Lawrence and its tributaries, being common, for example, in the small streams of Michigan.

As regards economic qualities, the characterization of the two species must be the same, except that the spike has generally a poorer form and is more often inferior in texture. The elephant's ear is broader, more rectangular in form, and heavier. The spike, as the name implies, is more elongate and thinner at the tip. The entire shell is sometimes very thin, as found in small streams.

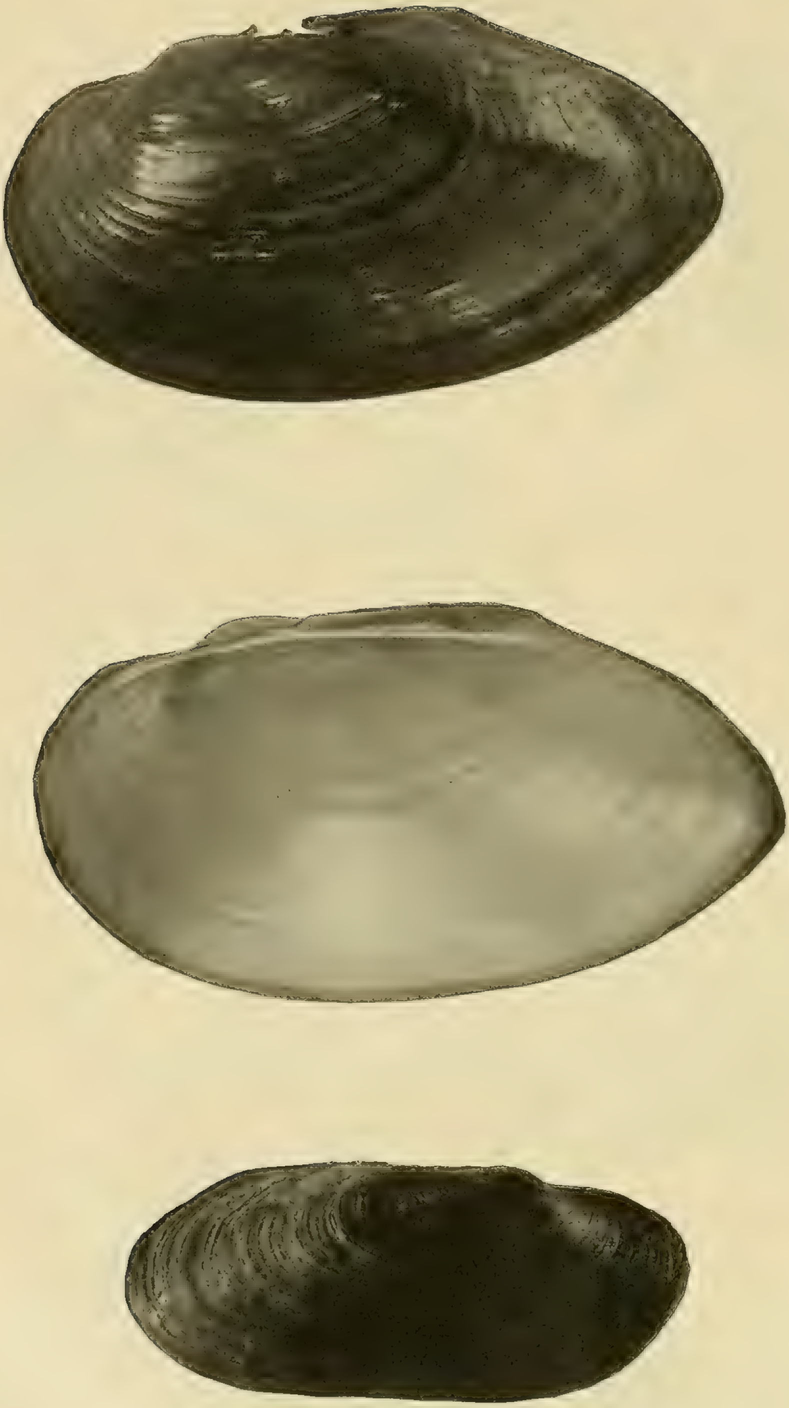
Both species generally have an appearance described as "solid," with a thick anterior (butt) portion and often with a very uneven surface. The color may be deep purple, reddish, or salmon, or occasionally white, and is often particularly beautiful. Unfortunately, coloration of any kind detracts from the commercial quality of a shell.

The thickness is good, but the most favorable feature of the shell is its texture, which is probably equal to that of marine shells. A manufacturer stated that cutting elephant's ears as compared with ordinary hard, white shells was like sawing a cake of firm soap as compared with sawing a board, and quoted a trade maxim: "When you find a pink shell you find a good shell"; that is, a shell which cuts well, although its color may make it undesirable. Analysis shows that the color is a feature of the organic matter in the shell and not of the crystalline or lime content. No clue has yet been obtained as to the nature of the coloring matter, nor has any entirely satisfactory method of bleaching been discovered, unless quite recently. If the color could be removed from the nacre by a cheap process that would not injure the texture or luster of the shell, the elephant's ear would become a most popular material.

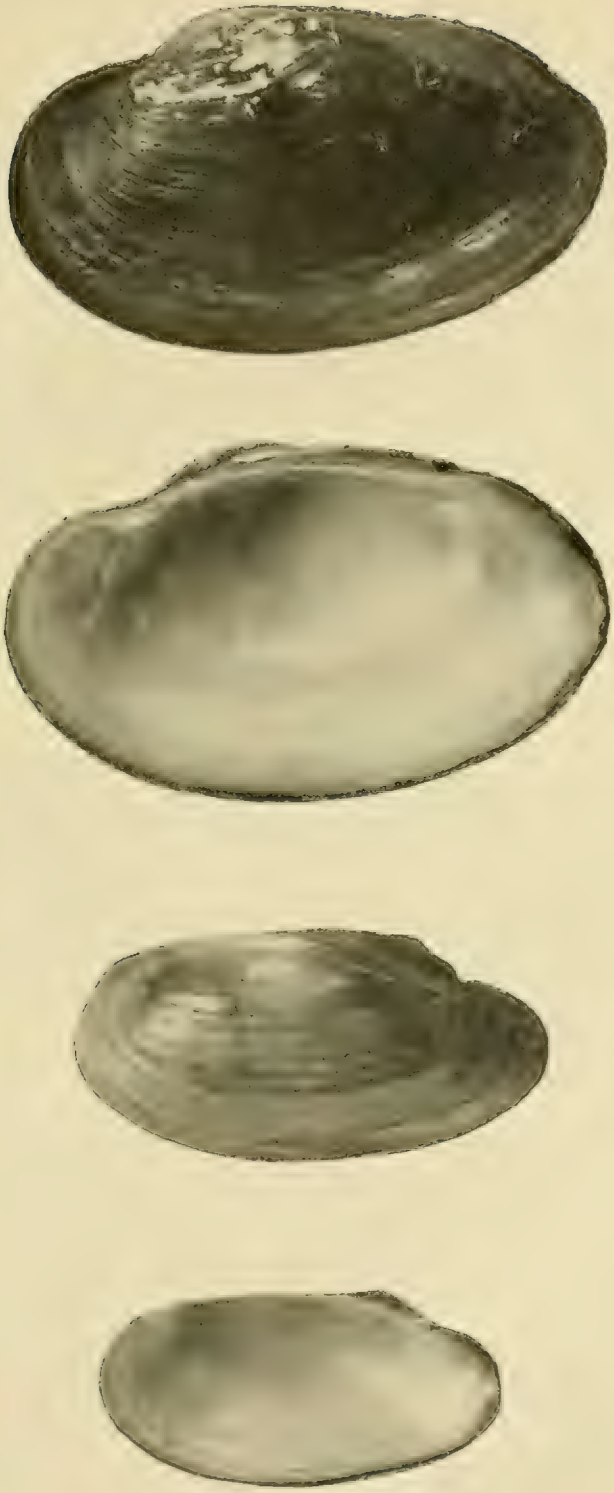
Elephant's ears, when purchased in mixed lots, can be used to advantage for the production of smoked-pearl buttons, if stained with silver nitrate. Occasionally carload lots of this shell have been purchased on the rivers toward the close of the season, but the practice has been discouraged by the tendency of shellers to throw in all manner of pink, purple, and otherwise useless material. Both species are used in making novelties. These mussels are probably short-term summer breeders.



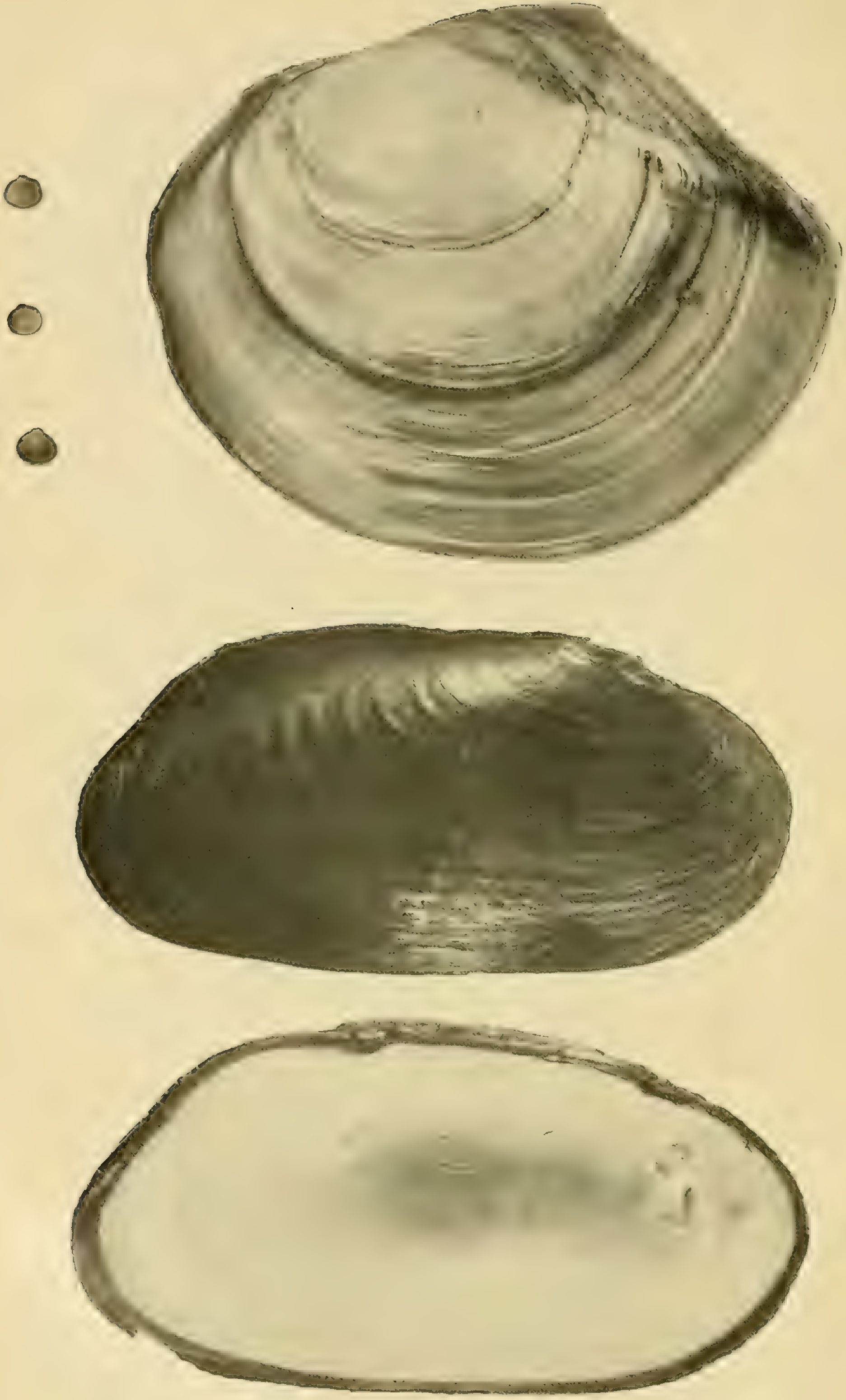
Upper pair: Elephant's ear, *Unio crassidens* (Lamarck), from Mississippi River. (See p. 34.)
Lower pair: Spike, *Unio gibbosus* (Barnes), from Mississippi River. (See p. 34.)



Upper and middle: Floater, *Anodonta grandis* (Say), from James River, S. Dak. (See p. 35.)
Lower: River pearl mussel, *Margaritana margaritifera* (Linnæus), from Freeport, Me. (See p. 35.)



Upper pair: Squaw-foot, *Strophitus edentulus* (Say). (See p. 35.)
Lower pair: Paper-shell, *Anodonta imbecillis* (Say). (See p. 35.)



Upper: Paper-shell, *Anodonta suborbiculata* (Say). (See p. 35)
Lower pair: Spectacle-case, *Margaritana monodonta* (Say), from Mississippi River. (See p. 35)
The three small shells in upper left-hand corner of plate are examples of *Sphæriidæ*, not fresh-water mussels.

NONCOMMERCIAL SPECIES.

We have completed the list of mussels of some economic value, numbering about 41 in all. There are approximately 533 species of the Unionidæ in North America (Simpson). Therefore, though granting a few omissions in the present list for species from localities little studied, it is discovered that the great majority of the American species are not of economic use. It is desirable to mention only a few of those forms which are most abundant and most familiar to shellers, or of particular interest for other reasons. Most of the noncommercial species are not numerous, and some are quite rare and restricted in distribution. Even in the economic investigations of fresh-water mussels it is necessary to devote some attention to the useless forms, because the study of such mussels often throws significant light upon the propagation, habits, and other relations of the economic forms.

The floaters, *Anodonta grandis* (Say) (Pl. XXIV) and other species, and the slop-bucket, *Anodonta corpulenta* (Cooper), are familiar shells of the slack waters along river shores or in sloughs. The shell is very thin and brittle and entirely useless. In one of the overflow lakes near Fairport there are found numbers of the very large and compressed *Anodonta suborbiculata* (Say) (Pl. XXVI). The most interesting species of *Anodonta* is the small, elongate, and paper-shelled *Anodonta imbecillis* (Say) (Pl. XXV), which has been found to develop without parasitism.

Another species which has been observed to develop without parasitism, but which has also been found to develop with a stage of parasitism on fish, is the squaw-foot, *Strophitus edentulus* (Say) (Pl. XXV), which is widely distributed in the Mississippi and Atlantic drainages. The Anodontas are not only thin-shelled but also are marked by the entire absence of hinge teeth; Strophitus has no teeth but a thickened hinge line. The shell is thicker than that of Anodontas but is too thin for commercial use; the nacre is generally of a dirty-yellowish color.

The spectacle-case is a thin-shelled mussel of the elongated form suggested by its name. The species is *Margaritana monodonta* (Say) (Pl. XXVI), of the Ohio, Cumberland, and Tennessee systems, but rare in the Illinois River. Its interest consists in the fact that it is the nearest relative of the river pearl mussel, *Margaritana margaritifera* (Linnæus) (Pl. XXIV), the principal pearl-bearing mussel of Europe and New England.

The paper-shells, as the name indicates, are too thin for utility, although of attractive appearance. They are very common and of wide distribution through the Mississippi Basin and elsewhere. The principal species are *Lampsilis gracilis* (Barnes) and *Lampsilis* (*Proptera*) *lævissima* (Lea).

Just as there are minnows among the fishes which are very small, even when adults, so there are small forms of mussels; an instance is afforded by the rainbow-shell, mentioned on an earlier page. One of the smallest of all true fresh-water mussels is *Lampsilis parva* (Barnes), which grows abundantly in the ponds at the Fairport station. It is narrow in form and never attains a length much exceeding 1 inch. Much of the skepticism of practical men regarding the results of investigations of the life history of mussels has been due to a lack of acquaintance with the small species. Time and again shellers or others have found reason to believe that mussels bring forth their young in an advanced stage of development, because they have found supposedly young niggerheads attached to, or inclosed within the dead shells of old niggerheads.

In nearly every case the little mollusks thus found are not the young of larger mussels, nor are they mussels of any character. It should be clearly and generally understood that, while all the larger clams of the rivers are mussels, there are clams which are not mussels at all, being markedly different in structure and development. There is no common name for these, but they pertain to several species of *Sphærium*, *Musculium*, and *Corneocyclas* (*Pisidium*) (Pl. XXVI). The usual diameter is 0.25 to 0.5 inch. They are frequently found attached to stones or to old shells in the mud. A dead shell may be found to be full of them. The Unionidæ (fresh-water mussels) and the Sphæriidæ live side by side in our rivers, but each family is more nearly related to different families of ocean shells than to each other.

SUMMARY.

Of the North American species of fresh-water mussels, more than 500 in all, we have named 66 as more or less familiar to the fishermen, but of these only 41 can be classed as having commercial value in the shell trade. Some of the others are valuable as producers of pearls.

Looking at the 41 used in manufacture more closely we find only 17 that are of real importance at the present time. It is desirable to name these separately.

Quadrula class:
- Niggerhead.
- Hickory-nut.
- Pimple-back.
- Maple-leaf.
- Monkey-face.
- Pig-toe.
- Ohio River pig-toe.
- Blue-point.
- Three-ridge.
- Washboard.

Lampsilis class:
- Mucket.
- Southern mucket.
- Lake Pepin mucket (fat mucket).
- Butterfly.
- Pocketbook.
- Yellow sand-shell.
- Black sand-shell.

Many manufacturers or buyers would reduce this list by omitting several of the species, but there would probably be little agreement as to the species to be eliminated.

The best of all species at the present time are the yellow sand-shell, the niggerhead, the southern mucket, and the Lake Pepin mucket, the last three being of approximately equal value. The yellow sand-shell has been used entirely for export and commands a price nearly double that of other species. Many niggerheads were exported a few years ago, causing a distinctly advanced price.

There is a great deal of variation in quality among the several species. Some shells are better for one purpose, while others are better for another.

Within the species there is variation according to the locality in which the mussels have grown. A mussel may have a shell of good quality in one stream and of poor quality in another. The differences may apply to color, luster, texture (firm, chalky, brittle, or hard), and form (shape and thickness).

Within the same mussel bed there may be differences in quality in the same species. We may find side by side pink muckets, white muckets, etc.

The shells of the Quadrula class show more uniformity in quality over the entire region of distribution than those of the Lampsilis class.

Iridescence is best shown in the niggerhead and pimpleback groups, but only a very small percentage of truly iridescent buttons can be obtained in any case.

The requisite qualities are pearliness, luster, absence of color, and a texture firm but not too hard; and these qualities are as good in the better Lampsilis shells as in the better Quadrulas.

The most common defects for nearly all shell species are spotting or staining, due, in many cases, undoubtedly, to parasites, and natural nacre colors, such as pink, salmon, or purple. Stains are most common in sluggish rivers. Colored shells seem more prevalent in clear, shallow streams, but no universal rule has been observed.

Many of the tiny shells found attached to old shells are not young fresh-water mussels, as is often assumed by shellers, but belong to an entirely different family of bivalves.

PUBLICATIONS TREATING MUSSEL RESOURCES OF VARIOUS STREAMS.

COKER, ROBERT E.

1912. Mussel resources of the Holston and Clinch Rivers of eastern Tennessee. U. S. Bureau of Fisheries Document No. 765, 13 p. Washington.

1915. Mussel resources of the Tensas River of Louisiana. Economic Circular No. 14, U. S. Bureau of Fisheries, 7 p. Washington.

COKER, ROBERT E., and SOUTHALL, JOHN B.

1915. Mussel resources in tributaries of the upper Missouri River. (With description of shell found in the James River, Huron, S. Dak., July 27, 1913.) Appendix IV, Report, U. S. Commissioner of Fisheries for 1914, 17 p., 1 pl., 1 map. Washington.

DANGLADE, ERNEST.

1914. The Mussel Resources of the Illinois River. Appendix VI, Report, U. S. Commissioner of Fisheries for 1913, 48 p., 6 pl., including 1 map. Washington.

ELDRIDGE, JOHN A.

1914. The mussel fishery of the Fox River. Appendix VII, 8 p., Ibid.

ISELY, F. B.

1914. Mussel streams of eastern Oklahoma. Economic Circular No. 9, U. S. Bureau of Fisheries, 6 p. Washington.

MEEK, S. E., and CLARK, H. WALTON.

1912. The mussels of the Big Buffalo Fork of White River, Arkansas. U. S. Bureau of Fisheries Document No. 759, 20 p. Washington.

SHIRA, AUSTIN F.

1913. The mussel fisheries of Caddo Lake and the Cypress and Sulphur Rivers of Texas and Louisiana. Economic Circular No. 6, U. S. Bureau of Fisheries, 10 p. Washington.

[UTTERBACK, W. I.]

1914. Mussel resources in Missouri. Economic Circular No. 10, U. S. Bureau of Fisheries, 6 p. Washington.

WILSON, CHARLES B., and CLARK, H. WALTON.

1912. Mussel beds of the Cumberland River in 1911. Economic Circular No. 1, U. S. Bureau of Fisheries, 4 p. Washington.

1912. The mussel fauna of the Maumee River. U. S. Bureau of Fisheries Document No. 757, 72 p., 2 pl. Washington.

1912. The mussel fauna of the Kankakee Basin. U. S. Bureau of Fisheries Document No. 758 52 p., 1 pl., 1 chart. Washington.

1914. The mussels of the Cumberland River and its tributaries. U. S. Bureau of Fisheries Document No. 781, 63 p., 1 pl. Washington.

WILSON, CHARLES B., and DANGLADE, ERNEST.

1912. Mussels of central and northern Minnesota. Economic Circular No. 3, U. S. Bureau of Fisheries, 6 p. Washington.

1914. The mussel fauna of central and northern Minnesota. Appendix V Report, U. S. Commissioner of Fisheries for 1913, 26 p., 1 map. Washington.

Part 2. FRESH-WATER MUSSEL FISHERY.[a]

VALUE AND EXTENT OF THE FISHERY.

The fresh-water mussel fishery is older than the fresh-water pearl-button industry, since the mussels have been taken in the search for pearls since 1857 at least, although but locally and irregularly. The importance of the fishery, in its two phases of pearling and shelling, dates from the beginning of the manufacturing industry, in 1891. It is interesting to note that at the present time the value of the pearl product is equal to about one-half that of the shell product. In some streams, chiefly the smaller ones, the pearls bring a better return to the fishermen than the shells, the Black River of Arkansas being a notable instance; but generally the value of the shells is considerably greater than the return from the pearls; the usual ratio is about 2 to 1.

The present paper is intended to refer primarily to the shelling industry and to give somewhat briefly an account of the territory and methods of the fishery. Since the pearls are usually taken incidentally in preparing the shells, the pearling methods are essentially the same, except that in regions where pearling is almost the exclusive object the practice of cooking out is not followed, owing to the belief that heat is detrimental to the pearls. In the shell fishery many noneconomic mussels are taken and cooked out along with the commercial shells with the hope that additional pearls may be found.

It would be of interest to compare the shell production of earlier years with the more recent statistical data for the mussel fishery. The earliest available estimates of the mussel fishery are contained in Statistics of the Fisheries of the Interior Waters of the United States, by Hugh M. Smith.[b] The quantity of mussel shells taken in 1894 is stated at 195,500 pounds (equivalent to 97.75 tons), having a value of $2,737. The small quantity of shells and the high unit value indicate that the industry was in a very rudimentary condition then, when few shells were required, and those bought were by the pound. It is well known from other sources that, owing to the great abundance of shells in proportion to the market demands, the price soon reached a low level, about $5 per ton, fluctuating from $4 to $10; but the supply was such that the fishermen made better wages then than at the present time, when the price received per ton is many times higher.

Smith [c] states that in 1897, 3,502 tons of shells were taken in Iowa and Illinois with a value of $40,408, and in 1898, 3,641 tons with a value of $37,008. Almost the entire fishery was within the limits of these two States at that time. It would appear that the average price per ton was about $11.50 in 1897 and about $10 in 1898.

A census report for 1889 shows that 23,824 tons of shells were taken, with a value of $216,404 (average price, $9.04 per ton), and a census report for 1908 gives the tonnage as 38,133, worth $386,000 ($10.02 per ton).

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[a] Ernest Danglade, formerly assistant in the Bureau of Fisheries, aided materially in the preparation of the description of the methods of fishery.

[b] U. S. Commission of Fish and Fisheries: Report of the Commissioner for the year ending June 30, 1896. Washington, 1897.

[c] Smith, Hugh M.: The mussel fishery and pearl-button industry of the Mississippi River. Bulletin, U. S. Fish Commission for 1898, Vol. XVIII, p. 289-314. Washington, 1899.

The latest data are found in detailed statistical reports of the Bureau of Fisheries covering the territory of mussel fishery by sections.[a] In 1912 about one-third of the territory produced 19,715 tons, valued at $294,606, and another third produced in the following year 23,317 tons, at a value of $382,210. The remaining third, including the Mississippi River, canvassed for 1914, a year of very poor fishery, yielded 8,539 tons, bringing to the fishermen $148,960. It seems a fair estimate that the total production of shells varies in different years from 40,000 to 60,000 tons, with a value of from $800,000 to upward of $1,000,000 (not including the value of pearls sold). The shells consumed in manufacture in 1912 aggregated 55,671 tons.[b]

The territory surveyed for 1912 comprised the southern portion of the Gulf drainage and the southern portion of the Mississippi Basin up to and including the Ohio River and up to, but not including, the Missouri or its tributaries. Arkansas was credited with nearly one-half of the total production. The average price of shells in Arkansas was nearly $20 per ton, but the average ton price for the entire region was $14.94 (1912). The territory covered in 1913 was that north of the Ohio and east of the Mississippi. The Illinois and Rock Rivers were credited with more than half of the total product for this territory and year, and, although the average price of shells in those streams was about $14 per ton, the average ton price for the territory and year (1913) was $16.82.

For 1914 the survey covered the Mississippi River and its tributaries from Kansas northward. The Mississippi River produced more than three-fourths of the tonnage, and the average price per ton for that river was $19.47 per ton, as against $17.44 average ton price for all streams covered in the survey for that year.

Combining the three surveys, it is found that the average price per ton of all shells was $16 for that period. Shells have advanced so materially in price during the years from 1914 to 1919 that the average price per ton is now about 100 per cent higher.

The history of the fresh-water mussel fishery since the beginning of the button industry has been marked by a continual extension of territory from the point of origin on the Mississippi River near Muscatine, Iowa. The rate of spread has been directly correlated with the rate of depletion of the more central territory. At various times the Wabash, the Ohio, the Illinois, and the rivers of Arkansas (White, Black, and St. Francis) have taken turn as the principal seats of mussel fishery. That the spread of the fishery has not been to the eastward and southward alone is shown by the fact that the fisheries have been prosecuted in South Dakota and Kansas and extensively in Minnesota. Unquestionably Lake Pepin in the Mississippi River between Minnesota and Wisconsin has recently been yielding a greater quantity of shells per linear mile than any other stream or portion of a stream.

The principal mussel streams are listed in the table following. The total value of the pearl and shell product is shown, as well as the year of the survey, and the last column indicates what proportion of the total income of the mussel fishery in each stream is derived from pearls. The data are taken from the statistical bulletins previously cited.

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[a] [Fresh-water mussel fishery of streams tributary to the Gulf of Mexico from the Ohio River southward in 1912.] Report, U. S. Commissioner of Fisheries for 1914, p. 26–30. Washington.

[Fresh-water mussel fishery of streams tributary to the Great Lakes and the Ohio and Mississippi Rivers north of the Ohio and east of the Mississippi River in 1913.] Report, U. S. Commissioner of Fisheries for 1915, p. 64–69. Washington.

[Fresh-water mussel fishery of the Mississippi River and its western tributaries from Kansas northward in 1914.] Report, U. S. Commissioner of Fisheries for 1916, p. 55–57. Washington.

[b] [Fresh-water pearl-button industry of the United States in 1912.] Report, U. S. Commissioner of Fisheries for 1914, p. 31–34. Washington.

River.[a]	State.	Year.	Total value of shell and pearl products to fishermen at the river.	Pearl products in total.
				Per cent.
Mississippi	Minnesota, Wisconsin, Iowa, Illinois, Missouri	1914	$176,510	29
Rock	Wisconsin, Illinois	1913	150,696	21
Illinois	Illinois	1913	128,692	31
White	Arkansas	1912	122,748	38
Ohio	West Virginia, Ohio, Kentucky, Indiana, Illinois	1912	118,891	10
Black	Arkansas	1912	68,726	65
Wabash	Indiana, Illinois	1913	67,991	35
White, East Fork	Indiana	1913	45,080	19
St. Croix	Wisconsin, Minnesota	1913	37,032	63
St. Francis	Arkansas	1912	29,769	17
Okaw	Illinois	1913	23,970	25
Cumberland	Tennessee, Kentucky	1912	22,136	33
Caddo (Lake)	Texas	1912	20,000	100
Fox	Wisconsin, Illinois	1913	15,842	51
Muskingum	Ohio	1912	14,275	14
Neosho	Kansas, Oklahoma	1912	12,063	17
Pecatonica	Wisconsin, Illinois	1913	11,463	7
Tennessee	Tennessee, Alabama	1912	11,061	8

[a] Minor tributaries are included with the main stream.

Minor mussel streams not included in the foregoing table may be classified as follows: (1) Those with shell product exceeding pearl product in value and (2) those with pearl product greater than shell product. The streams in each of these two classes are as follows, the arrangement being alphabetical:

1. Big Sunflower, Miss.; Blue, Kans.; Bourbeuse, Mo.; Cedar, Iowa; Cottonwood, Kans.; Des Moines, Iowa; Eel, Ind.; Embarrass, Ill.; Grand, Mich.; Green, Ky.; Holston, Tenn.; Huron and Raisin, Mich.; Iroquois, Ill.; James, S. Dak.; Kalamazoo, Mich.; Kankakee, Ind. and Ill.; Little, branch of Red, Ark.; Little, branch of St. Francis, Ark.; Little Missouri, Ark.; Little Wabash, Ill.; Maple, Mich.; Marais de Cygnes, Mo. and Kans.; Maumee, Ohio and Ind.; Meramec, Mo.; Minnesota, Minn.; Mississinewa, Ind.; Muskegon, Mich.; Nebraska, Kans.; Ouachita, Ark. and La.; Osage, Mo. and Kans.; Pearl, Miss. and La.; Saline, Ark.; St. Joseph, Mich. and Ind.; Shell Rock, Iowa; South Skunk, Iowa; Tombigbee, Ala.; Tuscarawas, Ohio; White, West Fork, Ind.; and miscellaneous smaller streams.
2. Clinch, Tenn.; Duck, Tenn.; Iowa, Iowa; Sangamon, Ill.; and doubtless many creeks.

There are also probably a few mussel streams, especially in the South, which have not yet been surveyed.

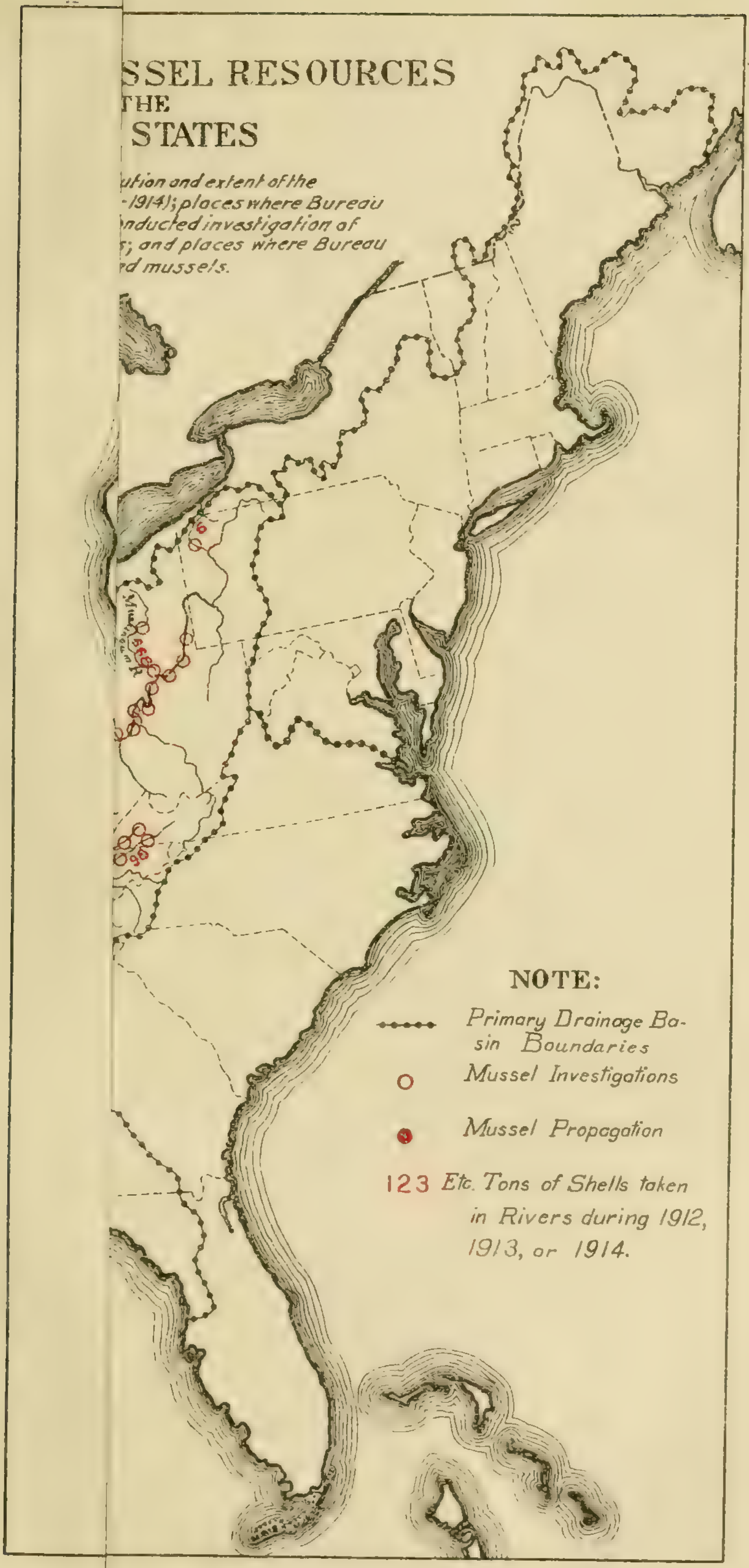
The mussel fishery is pursued more or less actively in the following 19 States:

Mississippi River or westward: South Dakota, Minnesota, Iowa, Missouri, Kansas, Arkansas, Oklahoma, Louisiana, and Texas.

Mississippi River or eastward: Minnesota, Wisconsin, Michigan, Illinois, Indiana, Ohio, Kentucky, West Virginia, Tennessee, Louisiana, Mississippi, and Alabama.

Manufacturing States, such as New York, Massachusetts, New Jersey, Pennsylvania, and Maryland, are indirectly interested in the mussel fishery on account of having manufacturing industries based upon the shells received from the mussel streams. Thus, at least one-half of the States have an immediate interest in the preservation of the mussel resources.

The accompanying map shows the territory of the fishery and the principal mussel streams.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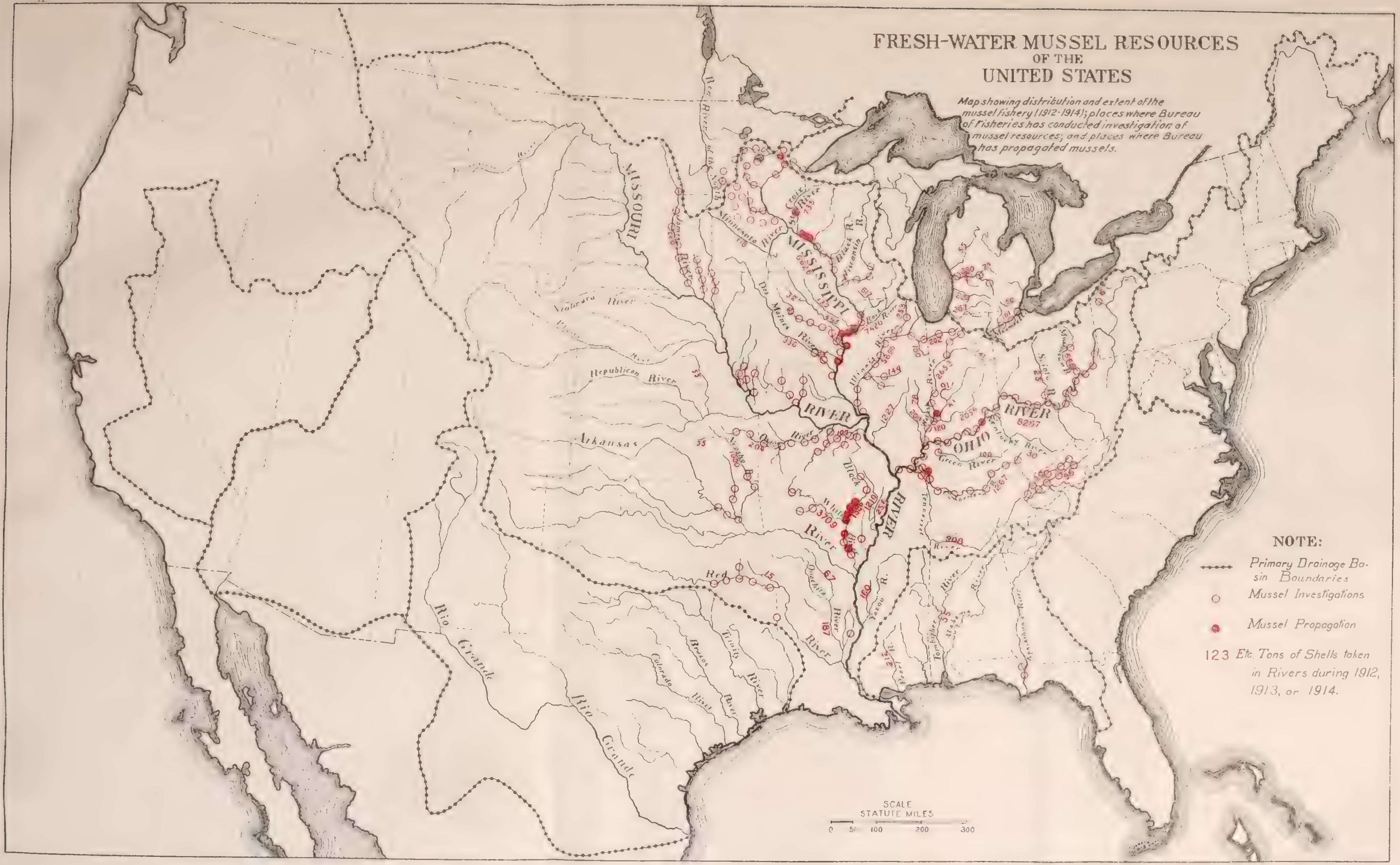
NOTE:
Primary Drainage Basin Boundaries
Mussel Investigations
Mussel Propagation
123 Etc. Tons of Shells taken in Rivers during 1912, 1913, or 1914.



FRESH-WATER MUSSEL RESOURCES
OF THE
UNITED STATES

Map showing distribution and extent of the mussel fishery (1912-1914); places where Bureau of Fisheries has conducted investigation of mussel resources; and places where Bureau has propagated mussels.

NOTE:
Primary Drainage Basin Boundaries
○ Mussel Investigations
● Mussel Propagation
123 Etc. Tons of Shells taken in Rivers during 1912, 1913, or 1914.
SCALE
STATUTE MILES
0
50
100
200
300
MISSOURI
RIVER
MISSISSIPPI
RIVER
OHIO
RIVER
Red River of the North
Minnesota River
St. Croix River
Black R.
Wisconsin R.
Iowa River
Des Moines River
Rock River
Illinois River
Wabash River
Niobrara River
Platte River
Republican River
Arkansas
Osage River
Neosho R.
Black River
White River
Green River
Kentucky River
Cumberland River
Tennessee River
Scioto R.
Muskingum R.
Maumee
Red River
Ouachita River
Yazoo R.
Pearl R.
Tombigbee River
Alabama River
Apalachicola River
Rio Grande
Colorado River
Brazos River
Trinity River
Rio Grande
3709
8257
7420
735

SOME LOCAL AND TEMPORARY ASPECTS OF THE FISHERY.

The mussel fishery is a permanent and important industry, and in scarcely any locality where a shell fishery was once established has it ever been entirely abandoned; yet the intensity of the fishery in any locality may vary from year to year, as it is subject to a variety of influences, such as the demand for shells of certain qualities, the stages of the river, the condition of local industries or of the button industry, and the degree of exhaustion of the material.

The natural movement of the territory of fishery from regions more or less depleted to virgin streams has been discussed on page 39. A limitation upon the rate of expansion is imposed by the cost of transportation of the product from its original source to points of manufacture; but the principal determining factor in this respect is the quality and abundance of the material, since cutting plants will follow the fishery if justified by the nature of the available material. There may be given, first, some illustrations of the extent of the fishery in certain localities as they have come more or less directly under the observation of the writer.

The statistical bulletins published by the Bureau show the value of the product from the several streams, each taken as a whole, but the high productivity of certain beds before the process of depletion has advanced is not brought out in such reports. In the Illinois River in 1909 there were estimated to be about 2,600 boats engaged in the mussel fishery. One hundred or more boats would be engaged upon the same bed at one time, and, as a consequence, cutting plants sprang up all along the river. In 1911 the writer counted 125 mussel outfits lying idle upon the banks at one point, Merdosia, Ill., while some 15 or 20 were engaged upon the river at varying distances from the town and mostly out of view. The exhaustive effect of the fishery of the three years preceding 1911 accounted in some measure for the number of idle boats. In 1912 only about 400 boats could find occupation in the mussel fishery on this river, although a more effective method of capture (the dip net) had been devised.

In each of the two years 1912 and 1913, according to reliable information, about $20,000 worth of shells and pearls were marketed at Madison, Ark., a village of about 300 inhabitants. This represented the product of beds largely depleted but yielding shells of high quality.

In 1910, 1,600 tons of shells, principally niggerheads, were taken in the rapids above Keokuk, Iowa, mostly within a stretch of 4 or 5 miles, and these shells represented a value of about $30,000. In 1912 a little over 400 tons were taken in the same region. This bed has been lost to the industry since the submergence of the rapids following the construction of the dam.

In the immediate region of Le Claire, Iowa, and Port Byron, Ill., in 1910, about 700 tons of shells were taken, representing a value of some $14,000. Fishing at Le Claire, Iowa, began about 1897, and the large catch of 1910 was due to the condition of very low water, enabling the fishermen while wading to pick by hand the shells which could not be taken in ordinary stages because of the rocky character of the bottom.

These are not insignificant figures, considering that the harvest was reaped without expense of planting or cultivating. Such harvests can not, however, be often repeated, since the rate of removal exceeds the rate of natural replenishment.

The variable quality of the several species of mussels is discussed on page 16 of Part I in connection with the commercial qualities of shell. Only a word is necessary in this connection in regard to the geographic aspect of the subject and its effect upon the fishery. The profitableness of shelling in any locality is determined largely by the quality of the more abundant species. Some species are nearly always rare, or, at least, are never the dominant species of mussel beds. Nevertheless it is a striking feature of the mussel fishery that in different streams or in different portions of the same stream different species may dominate. We may have niggerhead streams, mucket streams, pig-toe streams, etc., but we do not expect to find maple-leaf streams, buckhorn streams, or butterfly streams, although these forms are widely distributed.

In that portion of the Mississippi constituting Lake Pepin, the Lake Pepin mucket comprises as much as 60 per cent of the catch from many beds, in spite of the large number of other common species present. Since this shell as found in Lake Pepin is of the best quality in so many respects, the region of the lake may be expected to be the scene of active fishery as long as the beds are reasonably productive.

Certain portions of the Mississippi River may show from 50 to 85 per cent of niggerheads against all other species combined. At Le Claire, Pleasant Valley, and other points above Davenport, Iowa, 75 or 80 per cent of niggerheads are reported. Counts of shell piles above Keokuk, October, 1912, showed 80 per cent niggerheads, and 10 per cent monkey-faces, while 7 other species constituted the remaining 10 per cent. There were a few discards not included in the count. A similar predominance of niggerheads is observed in Arkansas, especially in the White and St. Francis Rivers. In the St. Francis near Madison, Ark., in 1913, about 16 species were taken, but 75 per cent were niggerheads. In such regions one may expect a steady fishery until the beds are nearly exhausted. It is reported that in the lower Pearl River of Mississippi and Louisiana the niggerheads constitute more than 99 per cent of the mussels in beds that have been fished, but the quality of the shell has not been definitely ascertained; if the report of percentage is correct, these beds are the most remarkable known for the predominance of one species.

In the Illinois River Danglade[a] found that in various beds blue-points may constitute 50 to 60 per cent of the catch, washboards 23 to 50 per cent, and warty-backs as much as 31 per cent. His observations regarding the river as a whole are succinctly expressed by the statement: "The Illinois is distinctly a washboard, blue-point, and warty-back river."

In piles of shells taken near Havana, Ill., washboards and blue-points constituted 95 per cent of the shells, while nine other species constituted the remaining 5 per cent. The fortune of the fishery in this stream will necessarily fluctuate with the demand for that class of shells, which is not at all constant. At times there may be a strong demand for blue-points and washboards for the making of buttons of the larger sizes; but, except with such a demand or with an excessive call for the higher-class shells, the market will not be the most favorable.

In the Ohio River, the Ohio River pig-toe may constitute as much as 80 per cent of the mussels of a bed, but this species is never in high favor; mixed in with the predominant species, there is always a certain number of mussels of other species, some of which may be of superior quality.

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[a] Danglade, Ernest: The mussel resources of the Illinois River. Appendix VI, Report, U. S. Commissioner of Fisheries for 1913, 48 pp., 6 pl. including 1 map. Washington, 1914.

In the Cumberland River[a] the Ohio River pig-toe is reported to run as high as 95 per cent of the catch from one bed, while the valuable southern mucket is found in the proportion of 40 per cent in some beds in this river.

An unusual export demand, causing a high price for the best shells, will tend to throw the domestic trade back upon second-grade material, and thus stimulate the fishery in regions of inferior-shell product. On the other hand, a slack in exports such as now prevails makes the best shells more readily available to American manufacturers and discourages the fishery for poorer shells.

Taking the principal mussel streams previously listed, we find the average price per ton for shells on the bank in the years 1912–1914 to be as follows. These figures are of value now only as indicating the relative values of shells from the several rivers.

RELATIVE VALUES OF SHELLS IN VARIOUS STREAMS, BASED ON SURVEYS OF 1912–1914.

River.	Year.	Average ton price.	River.	Year.	Average ton price.
Fox	1913	$22.09	Wabash	1913	16.51
White, Arkansas	1912	20.44	Rock	1913	16.01
St. Francis	1912	20.39	Illinois	1913	14.95
Muskingum	1912	20.00	Okaw	1913	14.70
Mississippi	1914	19.47	Ohio	1912	12.88
St. Croix	1913	18.87	Cumberland	1912	11.73
White, Indiana	1913	17.79	Tennessee	1912	11.18
Pecatonica	1913	17.31	Neosho	1912	9.97
Black	1912	17.19			

Since mussels are always sold by the ton, it is of interest to note the number of shells constituting a ton in selected cases. No general statement is possible, since the number necessary to make a ton varies with the species, the size, and the thickness. The washboard shells of the upper Illinois averaged about a pound a pair, while those of the lower river averaged less than half a pound but were of better quality. The following counts are selected from a table given by Danglade and from counts made by the writer:

Species.	Locality.	Number of pairs of shells (from one mussel) per ton.
Washboard	Chillicothe, Ill	2,000
Do	Hardin, Ill	4,800
Blue-point	Chillicothe, Ill	3,000
Do	Hardin, Ill	6,800
Warty-back	Meredosia, Ill	14,200
Do	Florence, Ill	17,200
Niggerhead	do	7,400
Do	Clarendon, Ark	20,500–27,000
Yellow sand-shell	Madison, Ark	6,000
Lake Pepin mucket	Lake City, Minn	12,000–14,000

The table next following shows the number of pairs of shells (equivalent to number of mussels) of different species and sizes and from different localities, making a ton as weighed and measured at a factory. The data comprised in this table are not strictly comparable to those in the preceding table, since the preceding table is based upon the shells taken from the river, and many of the smallest shells are lost before reaching the factory.

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[a] Wilson, Charles B., and Clark, H. Walton: The mussels of the Cumberland River and its tributaries. U. S. Bureau of Fisheries Document No. 781, 63 pp., 1 pl. Washington, 1914.

Species.	Locality.	Average size.		Pairs of shells per ton.
		Length.	Width.	
		Inches.	*Inches.*	*Number.*
Blue-point	Mississippi River, Grafton, Ill	3.82	2.81	4,500
Do	Sunflower River, Miss	3.50	2.56	5,500
Butterfly	White River, Ark	3.00	2.44	9,000
Lake Pepin mucket	Mississippi River, Lake City, Minn	3.17	1.92	10,000
Maple-leaf	White River, Ark	2.54	2.00	11,000
Monkey-face	Mississippi River, Fairport, Iowa	3.00	2.43	8,000
Mucket	Fox River, Wis	4.67	2.80	6,800
Do	Mississippi River, Fairport, Iowa	4.47	2.60	5,000
Do	Wapsie River, Waverly, Iowa	4.98	2.95	5,500
Niggerhead	Mississippi River, Fairport, Iowa	3.56	2.81	4,000
Do	Sunflower River, Miss	2.95	2.20	6,500
Do	White River, Ark	2.58	2.14	9,000
Pig-toe	do	2.23	2.00	13,000
Pimple-back	do	2.10	2.00	16,000
Pocketbook	Fox River, Wis	4.90	3.35	5,000
Do	Wapsie River, Waverly, Iowa	5.10	3.29	4,000
Three-ridge	Fox River, Wis	4.33	3.33	4,800
Washboard	Mississippi River, Fairport, Iowa	5.75	4.12	2,000
Do	Mississippi River, Grafton, Ill	4.40	3.10	4,500
Yellow sand-shell	Mississippi River, Fairport, Iowa	4.72	2.33	6,000
Do	do	4.23	2.00	9,000

Many of the shellers are nomadic and therefore move readily with their launches from a region of poor fishery to a better locality. It is often the case, however, that in times of low water, when the mussels are easily obtained, the farm hands, miscellaneous laborers, and others engage temporarily in shelling, using any kind of available equipment or collecting by hand. It is in such cases that good beds are often rapidly and seriously depleted.

A noteworthy difficulty encountered in some places where the quality of shells is good is the high cost of transportation. In regions remote from manufacturing centers it is therefore advisable to have cutting plants, so that the expense of shipping the waste portions of the shell may be obviated. A cutting machine costs about $16. The cost of a plant of 12 machines, complete, with all equipment except power, was about $400, as computed in 1914. In 1919 a cutting machine of improved type sells for $28 and a 12-machine outfit is estimated at $725.[a]

DEPLETION OF THE MUSSEL RESOURCES.

It has been mentioned that the extension of the fishery has been directed by the depletion of the mussel beds in the regions first worked. Generally speaking, it may be said that no stream or region has been entirely exhausted, but wherever a mussel fishery has once existed it has continued in operation to this time, although in reduced activity and with much irregularity.

The history of a shell bed in typical cases may be described. When first fished, there is usually a large proportion of very old shells which are coarse and heavy and often much eroded. After the first year or two the yield of the bed is chiefly the medium-sized shells of the best quality. In the last stages the larger shells constitute a gradually decreasing proportion, while the smallest shells, the very infants, indeed, form a steadily increasing proportion. Here is a fatal defect of the present manner of fishery. The rate of depletion is automatically accelerated, since the fishermen are taking two or three for one. Where formerly from 5,000 to 10,000 mussels, more or less, constituted a ton, at a later time, when small shells prevail, each ton may represent some 30,000 mussels, as has been determined by repeated counts made by the writer in localities where the small shells are being marketed. The fact that the sheller can now take but a few hundred pounds a day, as against the former catches of half a ton or more, might lead one upon first thought to suppose that the beds thus automatically receive a measure of protection. The very contrary, however, may in practice be the case. The continued rise in price stimulates the sheller to save everything, and the last stages of impoverished fishery are thus the more exhaustive.

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[a] In referring to values and costs the writer feels obliged throughout this paper to give figures, when available, for both the years 1914 and 1919. While it can not be assumed that prices of 1919 are normal, it seems reasonably sure that prices will not return to the level of 1914.

When shelling in a depleted locality becomes quite unremunerative, it may be practically entirely abandoned and almost forgotten, until after some years, it is found that the growth and natural reproduction of the mussels have so replenished the bed that it has again become a profitable one, and general shelling is resumed. Usually, however, the local shellers keep engaged, though irregularly, upon the same bed, or more exhaustive methods are employed, and the cases of natural recuperation are therefore conspicuous by their rarity.

In view of the conditions just described, the Bureau has advocated the compulsory closing of portions of rivers for periods of years, in order that the mussel beds might have such a condition of rest and freedom from all injurious disturbances that the process of replenishment would be assured. It has also urged the adoption of size-limit regulations which would prevent the needless destruction of the small mussels. With such reasonable protective legislation, supplemented, preferably, by artificial propagation, the depleted regions generally might be aided to recuperate. Several States have in recent years enacted comprehensive mussel laws whose effective enforcement will go far to insure the perpetuation of the mussel resources and thereby the permanence of the mussel fishery and its dependent manufacturing industries.

There is no question that all of the better mussel streams are capable of supporting mussel resources many times as abundant as they do now, for they did so a score or less of years ago. For each stream, therefore, it is merely a question of whether common-sense measures will be applied to restore the abundance of mussels for the benefit of all or whether they will always exist only as scattering survivals of an over zealous fishery.

The conditions and the measures for protection have been fully discussed in other publications of this Bureau [a] and need not be enlarged upon here. It may be said, however, that there is no important stream in which the mussel resources now exist in anything like their former abundance. There have been published photographs showing fishing through the ice in the Mississippi River in the early days, where the persons are grouped closely, each one with a considerable pile of shells about the hole through which he worked with a rake.[a] Such photographs could not be duplicated now, for each sheller would have to work a large area, and probably no considerable quantity of shells could be taken without more ice cutting than the value of the product would justify, even at the higher unit prices prevailing. The practice of winter shelling has, therefore, been discontinued.

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[a] Coker, Robert E.: The protection of fresh-water mussels. U. S. Bureau of Fisheries Document No. 793, 23 p., 2 pl. Washington, 1914.

Coker, Robert E.: The utilization and preservation of fresh-water mussels. Transactions American Fisheries Society, Vol. XLVI, No. 1, New York, 1916.

Smith, Hugh M.: Fresh-water mussels. Economic Circular No. 43, U. S. Bureau of Fisheries, 5 p. Washington, 1919.

APPARATUS AND METHODS OF FISHERY.

BAR AND CROWFOOT HOOKS.

PRINCIPLE OF CAPTURE.—This method of mussel fishery is the one in most general use to-day, since it is adapted for the greatest variety of conditions, is easily operated even by the inexperienced, and the construction and maintenance involve slight expense. The method is based on the characteristic habits of fresh-water mussels, which lie habitually half embedded in the bottom, with the hinder end of the shell directed against the current and slightly gaping. If a stick or hook be inserted into the opening of the shell, the mussel at once closes tightly and will hold for a long time, even while being dragged over the bottom and hauled up to the boat. Mussels are thus sometimes accidentally taken on ordinary fishhooks, while pearl fishermen working in shallow water have long employed a sharpened stick that could be inserted into the opening of the individual mussel. The more elaborate apparatus now used was first brought to the notice of the rivermen of the upper Mississippi early in the spring of 1897, and its use soon spread throughout all of the commercial shell districts.

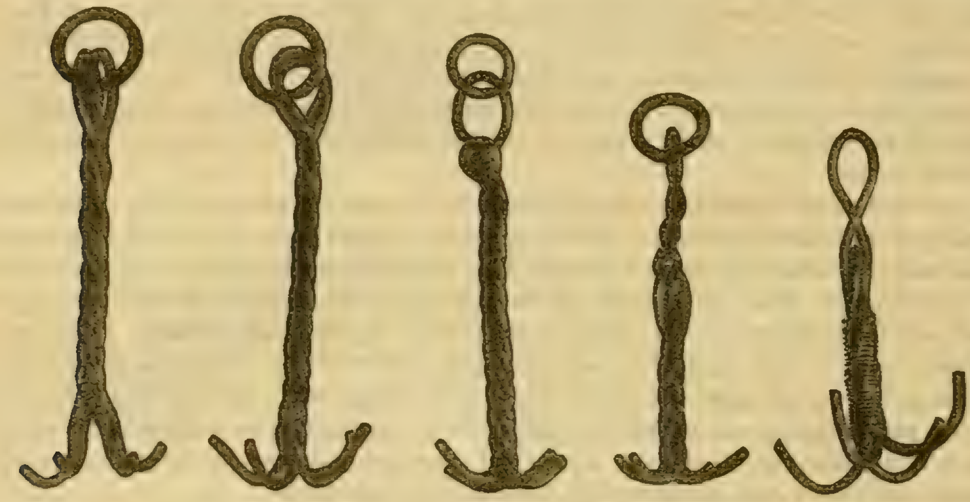

FIG. 1.—Various types of crowfoot hooks.

DESCRIPTION OF APPARATUS.—The crowfoot apparatus consists essentially of a bar or brail to which many short lines are attached bearing four-pronged wire hooks arranged at intervals (Pl. XXVII, fig. 1). By means of a towing line the bar is dragged above the bottom, while the hooks trail on the mussel bed in a direction parallel to the current. When a hook enters a shell opening, the mussel closes firmly upon the hook,

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[a] Smith, Hugh M.: The mussel fishery and pearl-button industry of the Mississippi River. Bulletin, U. S. Fish Commission for 1898, Vol. XVIII, p. 289–314. Washington, 1899. (See plates 67 and 68.)

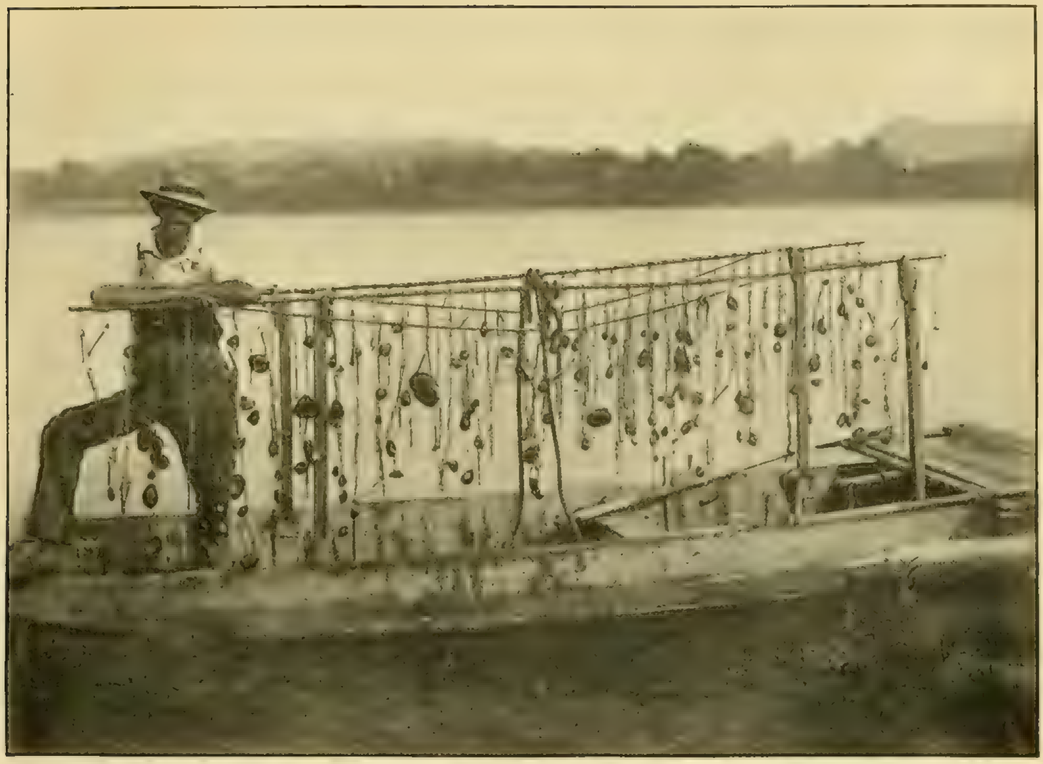

FIG. 1.—Bar and crowfoot outfit for taking mussels, consisting of john boat, two bars with crowfoot hooks, and the "mule" (lying on stern of boat). (See p. 46.)

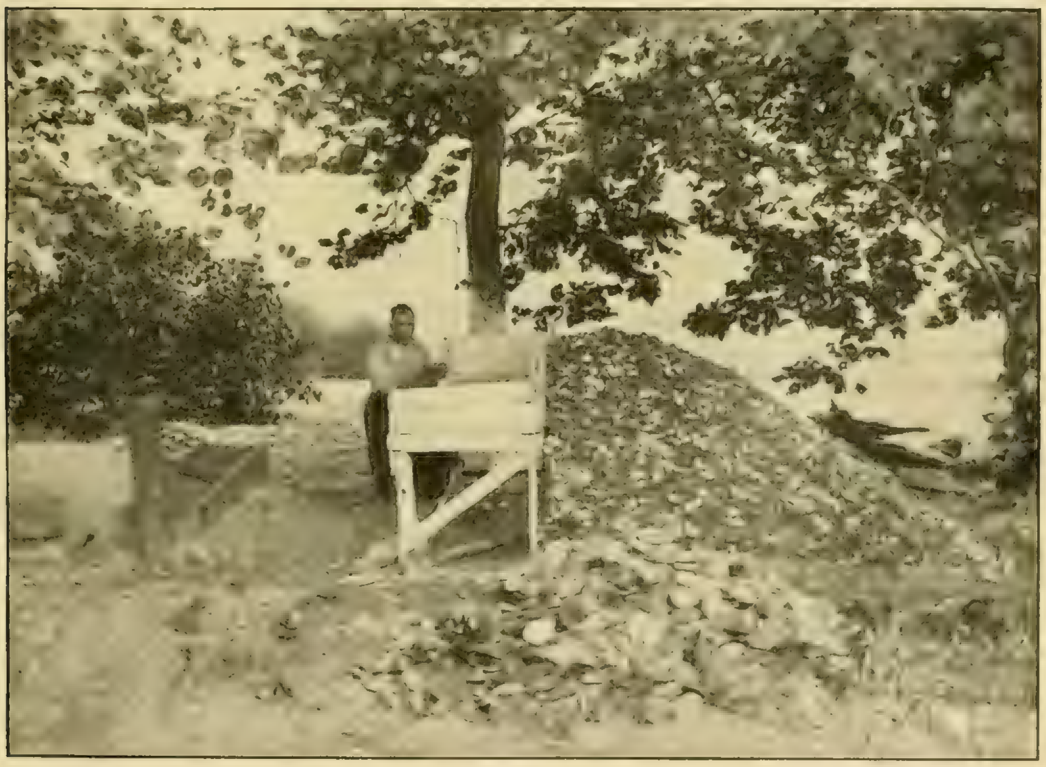

FIG. 2.—Shore outfit, consisting of cooker (at left), sorting table (center), and shells ready for sale. (See p. 60.)

and in consequence is dragged from the bottom. When the bar is raised after a suitable time, numerous mussels may be hanging from the hooks. The essential parts of this apparatus and the manner of its operation will be described in detail.

Hooks and mode of making them.—Although the principle of the crowfoot and the general method of manufacture are the same throughout the country, there is much variety in the style and size of hooks in use on the different rivers, and even in the same camps. Some of the most popular kinds of hooks are the single-eye, the double-eye, the ring, the wrapped, the untwisted or straight-wire hook, etc. (fig. 1). Manufactured hooks are obtainable on the market, but the mussel fishermen more commonly make their own hooks, employing odd moments for this purpose with a corresponding saving in expense.

The material is usually No. 11 galvanized or telephone wire. If very heavy work is to be done, a larger size, No. 9 or 10, may be taken, although hooks from the stiffer wire are more difficult to make and cause more trouble when the apparatus is fouled on the bottom; the bar may be entirely lost from a hang-up if the hooks will not straighten out before the line breaks.

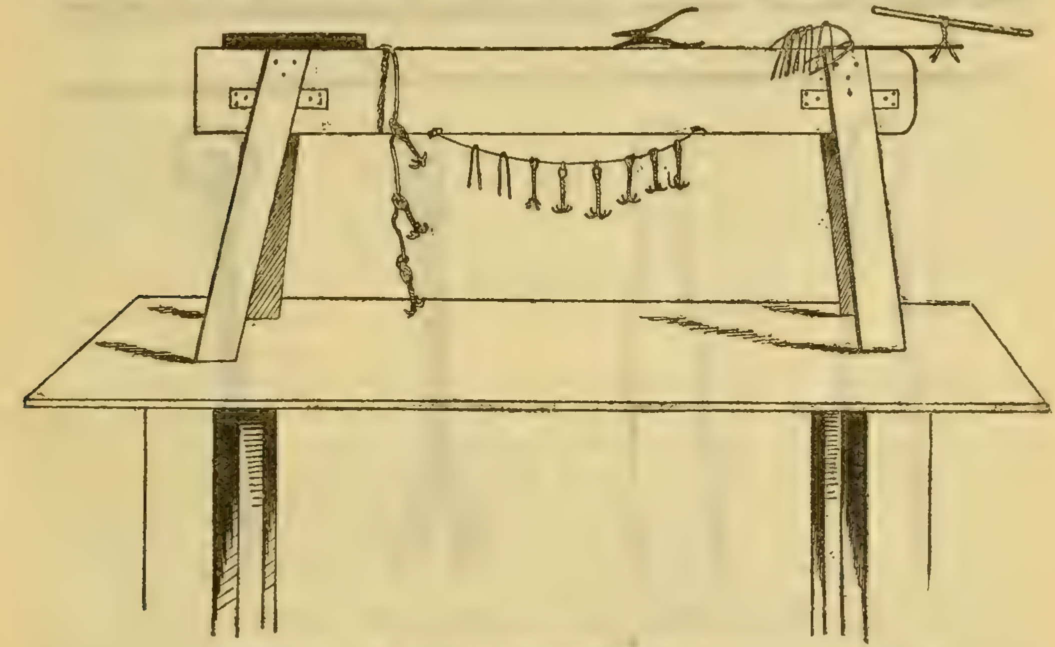

Fig. 2.—Process of making crowfoot hook.

To make a hook one needs only a bench, an iron vise, or, preferably, an iron strap or steel plate with proper holes drilled through, a pair of pliers, and a pin or short rod for the twisting process (fig. 2).

The iron strap or steel plate is usually from 6 to 8 inches long by 1.5 inches wide and 0.25 inch thick. Near one end four holes of sufficient size to admit the wire are drilled in the corners of a 0.75-inch square. Two or three additional holes are drilled in the opposite end of the plate, so that it may be fastened securely to a solid block, timber, or tressel of wood, leaving the end with the four small holes free. The wire is first cut into lengths of about 10.5 or 11 inches, or up to 14 inches for extra long hooks (fig. 3). The "needles" thus made are then bent into "hairpins" or loops, with the sides parallel or nearly so. Two loops are placed diagonally into the small holes of the square and are forced down to the face of the plate, leaving just room enough for the turning pin. The twisting is done by hand and continued until there is about 1 inch of straight wire remaining in the plate. The hook is withdrawn and is complete, excepting that the ends must be cut off at even lengths and bent to the desired angle with pliers or with a piece of hollow umbrella tube. In making the single-eye hook one loop is placed half an inch in advance of the other, when they are introduced into the iron strap. In order to obtain the best results in making hooks, the holes in the plate should be kept well greased. The process is well illustrated by figure 2, while some of the various patterns of hooks made by the mussel fishermen are shown in figure 1.

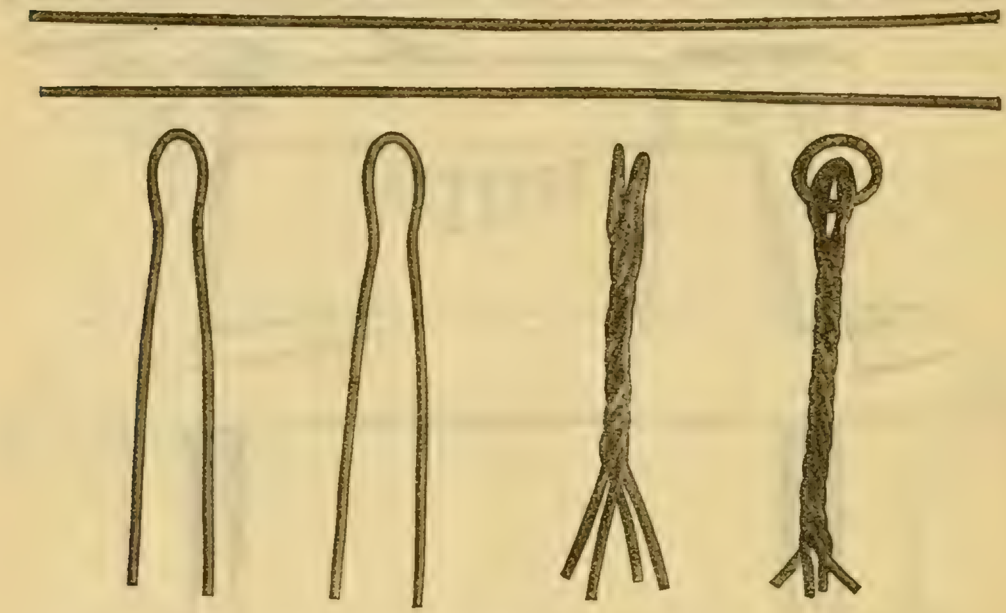

FIG. 3.—Stages in the process of making crowfoot hook; "needles," "hairpins," and nearly completed hooks.

Bar and lines.—The bar, or brail, consists of a black or galvanized iron gas pipe from 12 to 20 feet in length and with a diameter of from 0.75 to 1 inch (Pl. XXVII, fig. 1). Caps are used or wooden pegs are driven into the open ends of the pipe to keep out the water; otherwise the bar would fill with water and cause an undesirable slop when raised to the standards of the boat. The bars are occasionally supported by small wheels at the ends, to prevent the bar from disturbing the mussels before the hooks have reached them. This is generally unnecessary, because, while the boat is in motion, the bar is slightly raised from the river bottom, and only the hooks can touch the mussels. On a few rivers a wooden bar is used by some mussel fishermen, but it does not appear to be so popular or to give as satisfactory results as the iron bar.

The strings or lines for carrying the hooks consist usually of soft trot-lines of No. 96 or 120 size, and are about 3 feet in length. They are attached to the bar at intervals of from 4 to 6 inches by a half-hitch knot, which is easily tied and readily loosened if a new string is to be substituted. The soft line wears better than any other kind, especially where the bottom has much sand and gravel. Chains, or long wire links, are sometimes used in place of the cotton twine, but, although they last much longer, they are not often employed, owing to the extra weight and cost. Each line carries from two to six hooks, attached at intervals of sufficient distance to prevent successive hooks from interfering with one another.

The bridle is a small-sized rope, about 0.5 inch in diameter, and is attached to the bar near the ends. It is left loose, so that it may be tied to the main rope about 2 feet above the middle of the bar.

The main rope, or cable, is larger, being usually about 0.75 or 1 inch in diameter, while its length varies according to the depth of water, generally from 25 to 35 feet being required. The rope is tied to the middle of the bar and to the center of the bridle. To obviate difficulty from twisting and to make the rope available when desired for other purposes, the attachment to the bridle is usually made by a swivel snap and ring.

The mule.—An essential feature of the outfit with this method of fishery, under ordinary conditions, is the underwater sail or mule, as it is called. When the mussel fisherman is ready for work and the boat is over the shell bed, the bar is thrown overboard. The hooks of the bar catch in the river bottom, as well as in the shells, and thus, acting as anchors, will stop the progress of the boat downstream, unless additional power is supplied. In order to derive this power from the current, the mule is lowered into the river at the stern of the boat, to which it is connected by guide lines. Its broad surface is at right angles to the current, and the entire outfit is thus forced slowly down the river, stern first, in spite of the drag on the bottom. By means of the guide lines the mule is easily regulated to steer the boat at a desired angle over the mussel bed, or to avoid a familiar snag.

There are two well-known types of mules in use on the different rivers—the common frame type and the roll mule.

The frame type is rectangular in form, the outline or framework consisting of light strips or narrow boards about 3 inches wide by 0.75 of an inch thick, sometimes with a center strip extending from the middle of the bottom to a few inches above the top. In Plate XXVII, figure 1, a mule is shown lying on the stern of the boat; see also Plate XXIX, figure 1. The frame is covered with strong cloth, such as muslin, canvas, tarpaulin, gunny sacking, etc., which is left rather baggy in order to make the appliance more steady in the water; otherwise when the current strikes it at an angle it is liable to turn over, dart forward, and "kick." This characteristic accounts for its technical designation as "mule." It is connected to the boat by lines running from the four corners, excepting for those patterns having the center strip, when three connections are made with the lower corners and the top of the strip.

The roll mule is not used so extensively as the frame type, but it is very popular on the Illinois and some other rivers. It consists of a piece of canvas, tarpaulin, or heavy cloth cut according to the size and shape desired. An iron rod is attached to the bottom of the mule and a wooden bar at the top. To the four corners of the cloth small lines are secured for the purpose of adjusting the mule to the boat. This form of mule has the advantage over the other in that when not needed as a sail it can be rolled up and put out of the way in the boat or used as a tent against unfavorable weather. It is claimed that it is better adapted for steering the boat diagonally, and also that it does not kick.

There is much variety in the form and size of the mules, which are made according to the notions of the individual fisherman or in adaptation to the condition of the river. In a shallow stream the necessary surface is obtained by making the mule long and narrow, at times about 8 feet long by 15 inches deep. For deeper waters the sizes vary according to the strength of current and the drag of the bar; 2.5 by 6 feet and 3 by 7 feet are common sizes.

Boats.—The most satisfactory boat in use for the crowfoot method of fishery is the ordinary john boat, since it is inexpensive and may be made in the camps by the mussel fishermen themselves, according to their needs. Its length is from 14 to 20 feet, with a width at the center of from 3 to 4.5 feet, but it is always narrower at the ends. It has square ends, a broad, flat bottom, long rakes particularly forward, and is usually of light draft (Pl. XXVII, fig. 1).

When the john boat is built particularly for this method of fishery, all unnecessary interior parts are omitted, while the needed special appliances are added. These consist of two perpendicular uprights or standards on each side of the boat a yard or so from the ends, a cleat at the bow, and nails or pegs at the stern. The standards are about 4 feet high and are made of light strips of wood, with notches at the top for holding the bars. When the shelling is very heavy and the bars are difficult to raise, there are added at times substandards or short strips of wood projecting outward from the standards near the gunwale; in this case the bars when lifted are first placed upon the substandards and then transferred to the standards. At the present time nearly all of the john boats are equipped with gasoline engines of power commensurate with the size of the boats. In the Black River, Ark., some of the john boats are propelled by small stern paddle wheels operated by hand power with a vertical lever on the side of the boat.

OPERATION OF THE CROWFOOT BAR.—When the john boat and all the appliances are complete for this method of fishery, the boat is either rowed or propelled by gasoline power to the mussel bed upon which the work is to be done. After selecting the exact locality for the first haul, usually near the head of the bed, the mussel fisherman lowers a bar into the river in such a way that it will lie at right angles to the shore and drag parallel with it. The rope connecting the bar is played out until the latter is dragging freely and is then secured to the cleat. Occasionally two bars are used at the same time; the second bar being placed into the water a short distance in advance of the first and a little to one side, with a shorter rope connection.

Unless the current be very strong, which is seldom the case where a good mussel bed is found, it is necessary to bring the mule into operation; and this can be so adjusted by the guide lines as to make the outfit go very slowly or more rapidly as desired, as well as to cause the boat to sheer toward or away from the shore.

After making a haul of about 100 yards the bar is ready to be raised. The method of procedure is to remove the mule from the water and then slowly draw in the connecting rope until the bar can be grasped by the hands and raised to the tops of the notched standards. The other bar is put into the river, and the mule is again set. The shells are then taken from the hooks and are thrown into the bottom of the boat. The process is repeated until the bed has been worked over, when the boat is returned to the initial point or taken ashore, if a boatload of shells has been obtained.

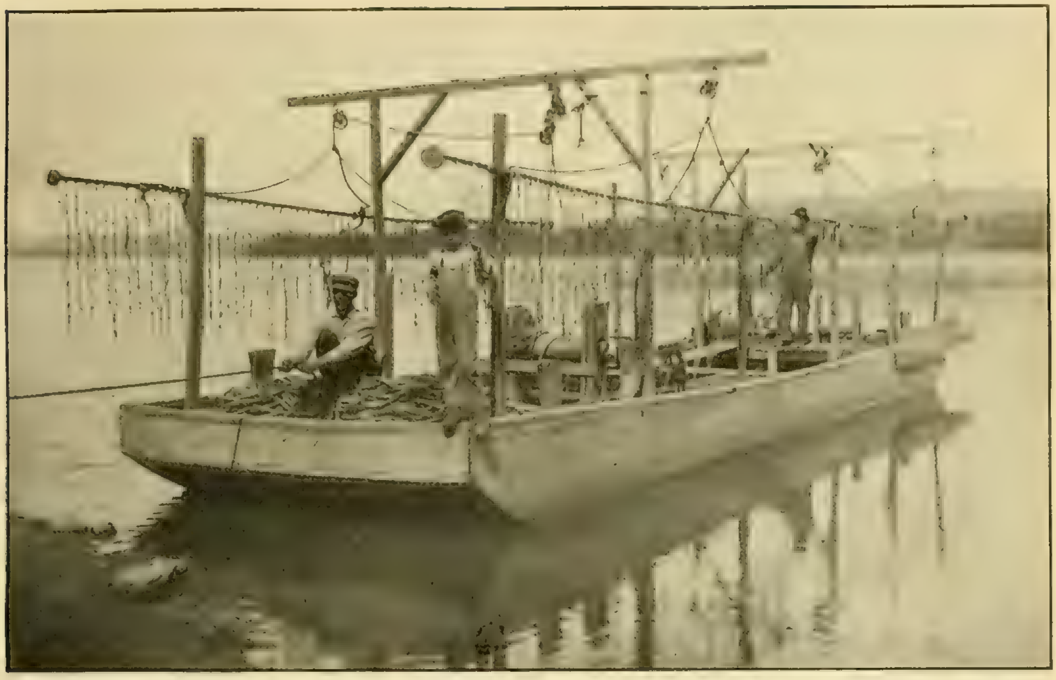

FIG. 1.—Barge with long crowfoot bars, employed on the Ohio River. Note rollers set on ends of bars to facilitate movement over the bottom. (See p. 51.)

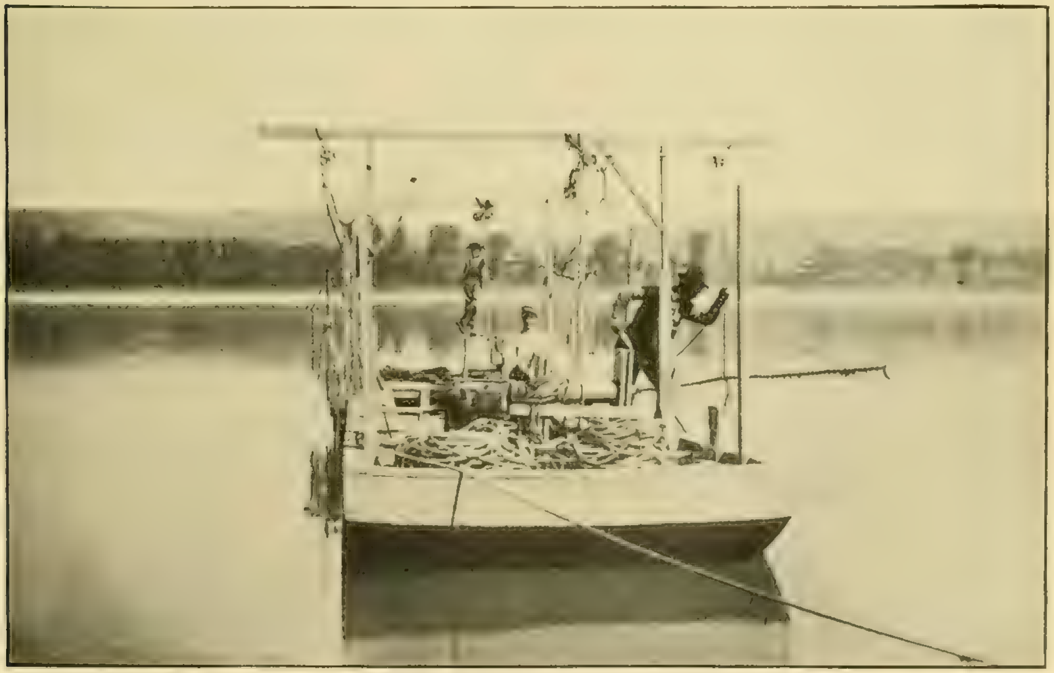

FIG. 2.—Lowering the crowfoot bar into the water, Ohio River. (See p. 51.)

Besides mussels the hooks bring up snags, small logs, and an almost unlimited variety of articles that have found their way into the river. There may be a greater or less number of larger hang-ups and other obstructions in the river, which may cause delay or the loss of a complete bar. No work is attempted in windy weather, ordinarily, on account of the trouble of handling the boat and the consequent danger of becoming entangled in the hooks or of being dragged overboard.

Where no current prevails, as in Lake Pepin, the propulsion of the boat was formerly accomplished by dropping an anchor with a very long cable attached to a windlass on the boat. The boat was then propelled away to a point where the bar was dropped. Turning the windlass by hand, the boat and bar were dragged over the mussel bed. The engine power itself was regarded as too violent, as well as too expensive, for the rate of movement desired in dragging. Now, however, the shellers on Lake Pepin generally use two boats, a flat boat attached broadside against the stern of a motor boat, T fashion. In this way two or even four bars may be dragged on the bottom at the same time, employing the motive power of the engine.

It is interesting to note that when this method was first brought into use in 1897, the parts of the apparatus were small and the method of employment crude. The bar was only from 4 to 8 feet long, provided with 16 or more hooks, and dragged by a rope from the stern of the boat. Two men usually operated in partnership, one man handling the apparatus, while the other rowed the outfit laboriously over the mussel beds. The hand motive power was later improved by the use of a driftboard or mule. By chance it was discovered that a similar effect was had when the boat was allowed to drift broadside to the current. Although this method is still used in some places, it has not gained general favor with the mussel fishermen, probably because, when the boat is used broadside, there is more or less danger of dipping water or swamping.

When the boat is used broadside, a series of cleats are placed on the gunwales of the boat in the middle portions. If a drag rope is attached to the middle cleat, the pull of the drag will be directly opposed to the current. If, however, it is desired to steer away from the shore, it is only necessary to shift the rope to another cleat, shoreward, or channelward, as the case may be, and the resultant force of the current is in the direction desired. If there is not sufficient force in the current to move the boat fast enough, a leeboard, or mule, may be used as readily as with the ordinary fore-and-aft position of the boat.

For work on a much larger scale than can be accomplished by means of the ordinary-sized boats there are occasionally employed heavy barges of a type illustrated in Plate XXVIII. These are used successfully on the Ohio River, near Vevay, Ind., and, though somewhat similar in construction to the usual john boat, they are much larger and more solidly built; the dimensions are, approximately, 10 by 40 feet. The barge is fitted with uprights and pulleys for handling the bars and with standards for holding them when raised. There are 4 bars 20 feet in length by 1.25 inches in diameter, to each of which are attached 76 strings, bearing 7 hooks each, thus making more than 2,000 hooks for the entire outfit. In operating this contrivance the bars at the opposite corners are lowered alternately into the river, so that as far as practicable two bars are always in the water. Because of the weight and the resistance of the bars on the bottom, a very large mule is used during a good stage of water or in a strong current. In the low water of summer a mule is of no avail; at this season of the year a cable 400 to 500 yards in length is used, one end of which is anchored down the river, while the other is hauled through a pulley by means of a two-horsepower gasoline engine, located near the center of the barge. The engine is also employed to assist in raising the bars from the mussel beds. The barge is towed from place to place by a small gasoline boat alongside or at the stern. By this method three men have been known to gather 3 tons of shells in a day in favorable localities in the Ohio River.

ADVANTAGES AND DISADVANTAGES OF THE METHOD.—Except where snags are prevalent, good success is had with the bar and crowfoot under a wide variety of conditions. The daily catch probably averages less than 500 pounds of marketable shells. In severely depleted regions only 100 to 200 pounds may be taken, while a half ton or more may reward the fisherman in better localities. The fishermen claim that the mussels or clams bite best in the spring of the year, on rising water, and early in the morning.

A serviceable john boat could be made in 1914 at a cost of from $10 to $15; and the bars, hooks, and lines at from $5 to $6 per pair; the necessary ropes cost from $2 to $3, making a total of from $17 to $24. However, if an engine of suitable power is installed in the boat an additional amount of about $50 to $100 should be added to the above sum. On the basis of the prices of materials in 1919, these costs appear approximately as follows: Boat, $23; bar, hooks, and lines, $10; ropes, $3; total, excluding boat engine, $36.

The method has these advantages: It is inexpensive, and not necessarily laborious; it is adapted for use in deeper waters where the hand rake or the tongs can not be used successfully, and it can be employed readily by the inexperienced.

The disadvantages of the crowfoot are not so obvious but are very important nevertheless:

1. The mussel beds are repeatedly dragged over by hundreds and thousands of hooks, with consequent possible injury to the mussels, especially the young. Gravid mussels, it is known, will often abort the immature spawn when disturbed.

2. Some mussels, after taking on the hooks, are pulled off while yet on the bottom with more or less injury. Experiments conducted at the Fairport station indicate that a large percentage of such mussels receive injuries from which they die. A considerable number of mussels were taken by hooks and by rakes; each set of mussels was divided into four lots, which were carefully balanced against one another in experimental ponds. After two months 38 per cent of the crowfooted mussels and only 5 per cent of the raked mussels had died.

3. The hooks take exceedingly small mussels, even down to 0.75 to 1 inch in length, which are not only useless for any economic purpose but are liable to a heightened mortality when thrown back into the river. The use of larger wire for the hook has been suggested, with a view to lessening the number of small mussels taken.

There are two or three designs of patented hooks on the market, and it is claimed that they have advantages over the ordinary kinds made by the mussel fishermen. One design, invented by the late J. F. Boepple, is like the ordinary twisted-wire hook, except that the wire prongs are compressed near the tips and finally expanded to form a ball or globular tip larger than the diameter of the wire. When the ball enters the opening of the mussel, the shell closes on the compressed neck, and it is very difficult for the mussel to fall off with the subsequent dragging on the bottom. These hooks are also slightly weighted by a wire wrapping at the lower end of the shank, and a dip in melted solder makes the entire hook less liable to untwist. Another hook, lately brought to the attention of the public and known as the "sanco-point" hook, has five prongs made in one piece and attached by means of a swivel to a center shaft. The tips are also globular to make a so-called locking device intended to prevent the escape of the captured mussels. For both of these designs, it is claimed that the small mussels are not captured on account of the enlarged tips, and that when the ordinary-sized mussels are once caught they do not fall off the hooks, so that no injured mussels are left in the beds.[a] These claims remain to be effectively demonstrated; but such improvements are eminently desirable and worthy of careful test, for there is no question but that the ordinary crowfoot hook is distinctly injurious and that its use should be permitted only for a brief time, allowing opportunity for effectively improving it or displacing it altogether with other equally efficient apparatus.

Meantime, mussel fishermen everywhere are urged to learn the use of other methods, for it is evident that an injurious mode of fishing will not be tolerated indefinitely. The shellers themselves will recognize the propriety of excluding from use, wherever it can be replaced, an appliance which is actually destructive of shells that are not taken or that can not be marketed when captured. Various other methods now in practical use will be described in the following pages.

DIP-NET DRAG.

Origin of the Method.—The dip net, as used in shelling was invented and introduced during the spring of 1911 at Peoria, Ill. It had long been known that Peoria Lake—that part of the Illinois River which broadens into a lakelike expanse above the dam at Peoria—contained large beds of commercial mussel shells of good quality, but previous to 1911 no suitable method of taking them had been devised. The various tools and appliances, as the bar and crowfoot hooks, tongs, scissor forks, etc., which had been operated so successfully in other mussel rivers of the Mississippi Basin and in the major portion of this river, proved unsatisfactory in Peoria Lake. There was urgent need for some contrivance that would collect the shells in deeper water, where practically no current prevailed, and the dip net came to fill this want.

It is not known who invented this appliance, but probably the idea developed by a combination of the principles of the ordinary dip net as used in fishing and the clam rake. At the present time this apparatus is used in Peoria Lake almost exclusively, none other being employed, except in places where the bottom conditions are unfavorable for the operation of the dip net. Within very recent years its use has extended to other parts of the Illinois River and to Lake Pepin. One dip net was seen on the White River of Arkansas in 1913, but it had not been put into use.

The dip net is simple in construction, and in operation; it is also inexpensive and especially suited to those rivers and lakes which have soft mud bottoms free from obstructions, such as logs and hang-ups, and where there is but little or no current.

Description of Apparatus.—There appears to be no definite standard or general specifications for this mechanism, and consequently there are no two alike; the blacksmiths make them according to orders and with the material at hand. However, the various designs and patterns are very similar, the main differences being the size of the hoop and the length of the attached net. The method of operation is the same for all of them.

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[a] Several tests made by J. B. Southall, shell expert of the Fairport station, indicate that about 30 per cent of the mussels catching on ordinary hooks are lost, while only about 15 per cent of the mussels catching on the Boepple hooks drop off.

The frame of the dip net consists of a heavy iron hoop of one piece flattened on one side. The general form, therefore, is somewhat triangular, the bottom being straight, while the two sides are curved and attached by bolts to a pole or handle 16 to 20 feet long (fig. 4 in text and Pl. XXIX, fig. 4). A large net of 2-inch mesh, made of small chain or trot-line and having a capacity of a bushel or more, is fastened to the hoop by means of chain links, and trails behind it. A short bridle attached to the two curved sides of the hoop lead forward to a single rope secured to the bow of the boat. To withstand the strain from dragging through the water and also to support the net with a heavy load of shells, the hoop is usually made of stout wagon-tire iron, about 2 inches wide by 0.25 inch thick. The straight bottom is from 18 to 36 inches in length; the edge is bent downward and usually provided with coarse teeth 6 to 8 inches long, and at times two or three additional teeth are riveted to the curved sides, near the bottom. However, in some hoops the teeth are omitted altogether, since none are needed where the bottom of the river is composed of very soft mud. The net varies in length

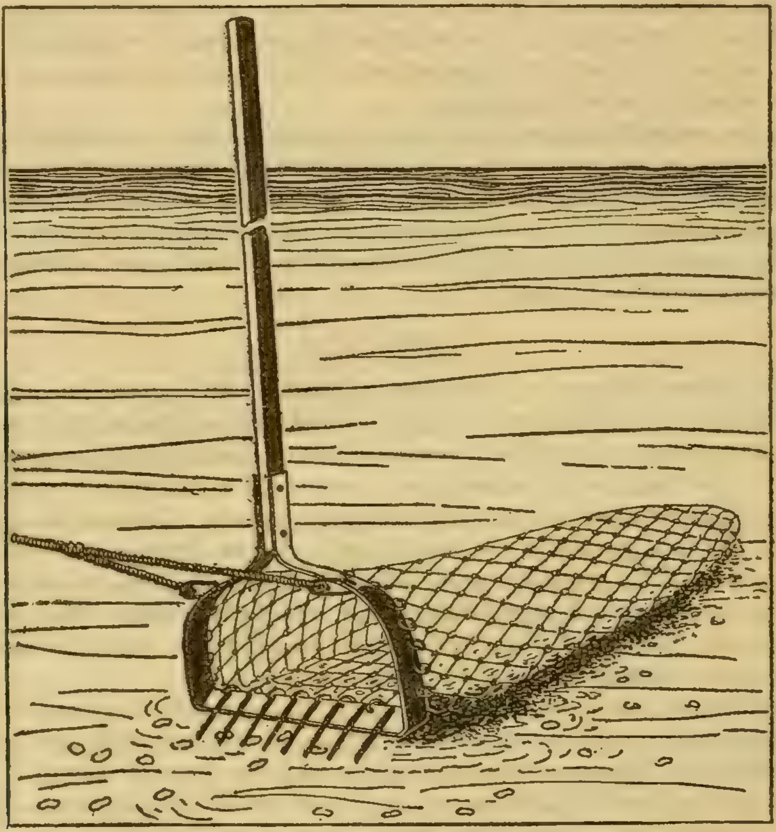

FIG. 4.—The dip net used in taking fresh-water mussels.

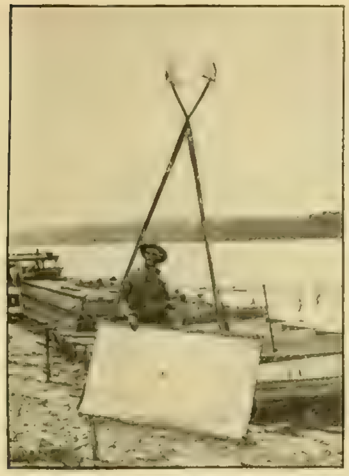

FIG. 1.—Shell tongs or scissors fork. The "mule" (in foreground) is not used with tongs, but in connection with crowfoot bars (in background). (See p. 56.)

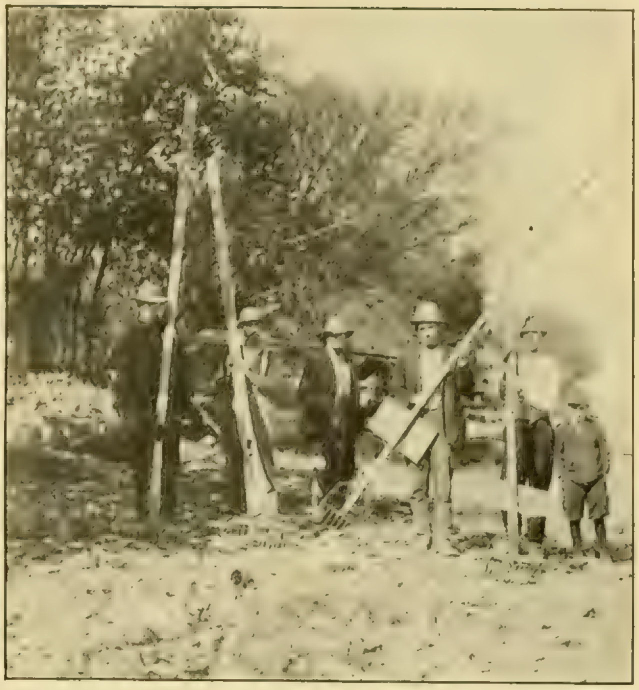

FIG. 2.—Two shell tongs (at left) and two shoulder rakes (at right). Note drift boards attached to handles of rakes. (See p. 56.)

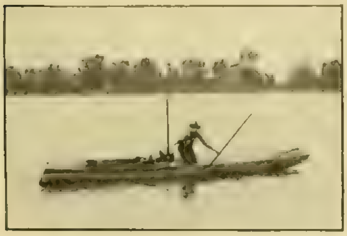

FIG. 3.—Taking mussels with the shell tongs. (See p. 56.)

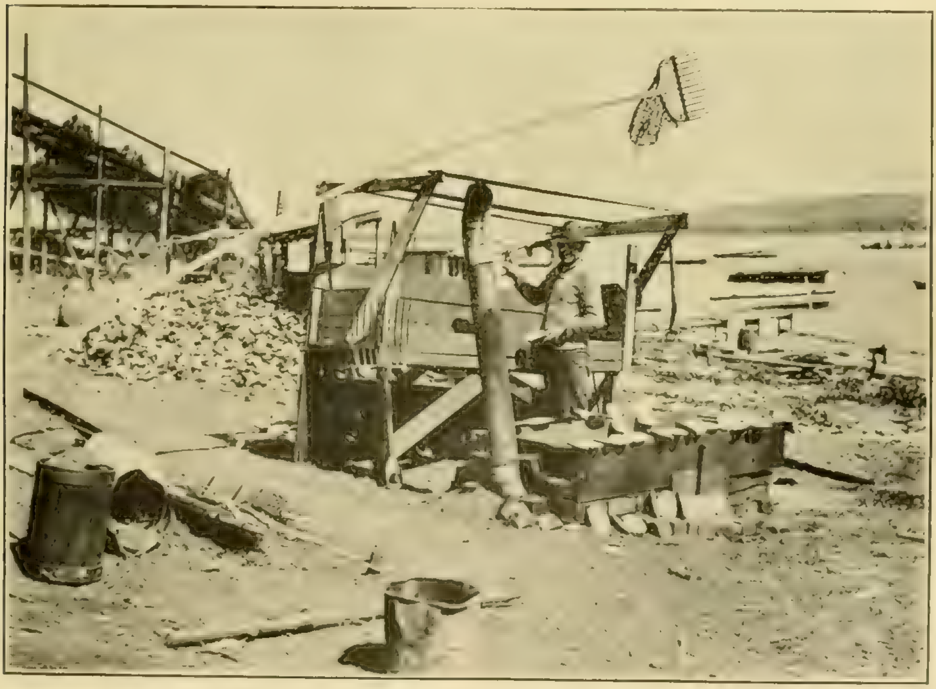

FIG. 4.—Dip net and forks with shore equipment. (See p. 54.)

from 3 to 4.5 feet, according to the size of the hoop; when not made of chain, it is usually tarred to insure longer life. Soft twine is preferred to hard twine; the sizes used range from 36 to 96, but the latter size is the one generally employed.

Power is a very important factor in the use of the dip net. The boat and engine, in fact, govern the size of the appliance, since it would be useless to work with a large dip net and very little power. Any ordinary john boat or launch, which the sheller may have, can be readily fitted up for use. Uprights or standards on the boat, as well as the mule, can be dispensed with. The engines are of the gasoline type and are from 4 to 20 horsepower.

The cost of the complete dip net, including the necessary ropes, is about $5 to $7, depending upon the size. Considering the good results obtained by this method of mussel fishery, together with the durability of the apparatus, the first cost is very small, indeed.

OPERATION OF DIP NET.—To operate a boat successfully, two men or a man and a boy are needed; one attends to the dip net and the steering, while the other looks after the engine and assists with the shells. When the boat is over the mussel bed, and running at full speed, the operator stands in the stern and steers with his foot or leg while manipulating the dip net with his hands. The apparatus is put into the water, usually at his right side, and when it reaches the bottom he bears down heavily on the handle. The towing line is attached, as previously mentioned, to the bridle at one end and to the bow of the boat at the other. The dip net, therefore, functions as a dredge, while the pole is handled by the fisherman in the stern in such a way as to change the angle of the net and cause it to dig into the bottom more or less deeply. Physical energy and endurance are required on the part of the operator, if the dip net is large and the power strong.

If the water be rather deep or the boat very short, the angle formed by the towing line and the upright handle may be too sharp for proper manipulation. In this case a boom pole is rigged out from the bow and a longer line attached to its forward end.

The teeth on the lower edge of the hoop dig up the mussels, which, due to the motion of the boat, roll into the net. Unless the net is placed at the stern in direct line of travel, the boat is retarded on one side and consequently makes a large circle over the mussel beds; this is usually desired. When the apparatus is raised after making a haul, the mud and small shells are washed out as well as can be done rapidly, and the contents are dumped into the bottom of the boat. The partner attends to the sorting out of the mussels, the trash and some of the dead shells being thrown overboard.

By this method of mussel fishery two men or a man and a boy have been known to take from 1,500 to 1,800 pounds of shells in half a day in a good locality.

ADVANTAGES OF THE DIP-NET METHOD.—The dip-net appliance is strongly recommended to the attention of mussel fishermen, as it is especially adapted for use on soft-mud bottoms and in waters which are without strong current and also where the depth is too great or the mussels too scattering for the successful operation of the rake or tongs. It may also be employed where there is a good current, providing the bottom conditions are satisfactory.

The method will be at a disadvantage in very hard or gravelly bottoms or where there are numerous obstructions; in the first case the net will become overloaded with rocks, and in the second the progress will be stopped altogether.

It is well to point out that the meshes of the net should be of such a size as to permit the small shells to pass through and remain at the bottom. Some small mussels will undoubtedly be held in the net by the mud and larger shells, but these can be culled out readily and returned to the water without any material injury.

It may be noted that occasionally some of the thinner-shelled mussels, such as the floater, paper-shell, etc., are pierced by the teeth of the dip net, which, of course, kills the mussel. These shells, however, are not now of any commercial value.

SHOULDER RAKE.

The shoulder rake can be used to advantage in comparatively swift water, especially when the bottom is not too hard and is free from hang-ups such as rocks and sunken logs. The implement consists of a metal rake about 1 foot long and provided with 10 to 12 coarse teeth or curved tines, which may be about 9 inches long (Pl. XXIX, fig. 2). The rake is securely bolted to a wooden handle 15 to 20 feet long, its length being adapted to the depth of water. A basket, made of poultry-wire netting, is attached to the rake and handle in such a way as to afford a concave receptacle for the shells. A small board, about 10 inches by 2 feet, is usually fastened to the handle approximately 1 yard from the base. The method of operation is rather simple, though laborious. The boat in which the work is carried on is anchored over the mussel bed, and the rake is placed into the river at the head of the boat and slowly worked down to the stern, when it is raised to the surface. The shells are thrown into the boat. The board attached to the handle offers resistance to the current, and thus is of considerable assistance in raising the rake, as well as in driving it downstream over the bed; it therefore has the same function of an underwater sail as the mule used in crowfooting, but the power of the current acts only upon the rake, and not upon the boat. The shoulder rake may be made from a coke fork. The tines are cut to the desired length, heated, and bent at right angles to the handle. A long handle must, of course, be substituted for the short handle of the coke fork.

The results of this method are generally satisfactory, if the shells are relatively abundant. Small shells inadvertently taken can be thrown back with assurance, generally, that they will live.

The shoulder rake is a common implement on the Mississippi River and other streams. On the St. Francis River, Ark., it is the principal method employed in the summer and fall, while the crowfoot is chiefly used in the high water of spring. The fork, to be described later, is also used in very low water.

SHELL TONGS.

The shell tongs, or scissor forks, are used to some extent on the upper Mississippi, the Cumberland, the White, and some other rivers where the work can be carried on satisfactorily in rather deep water. It is possible, of course, to work between the free spaces of a series of logs or other obstructions. It is essentially a grapple, consisting of two rakes, or forks, on the ends of long handles which are pivoted together about 2 feet from the lower end, after the fashion of a pair of scissors (Pl. XXIX, figs. 1, 2, and 3). The method of its operation is similar to that of the oyster tongs; the appliance is lowered into the water from an anchored boat, then by bearing down on the

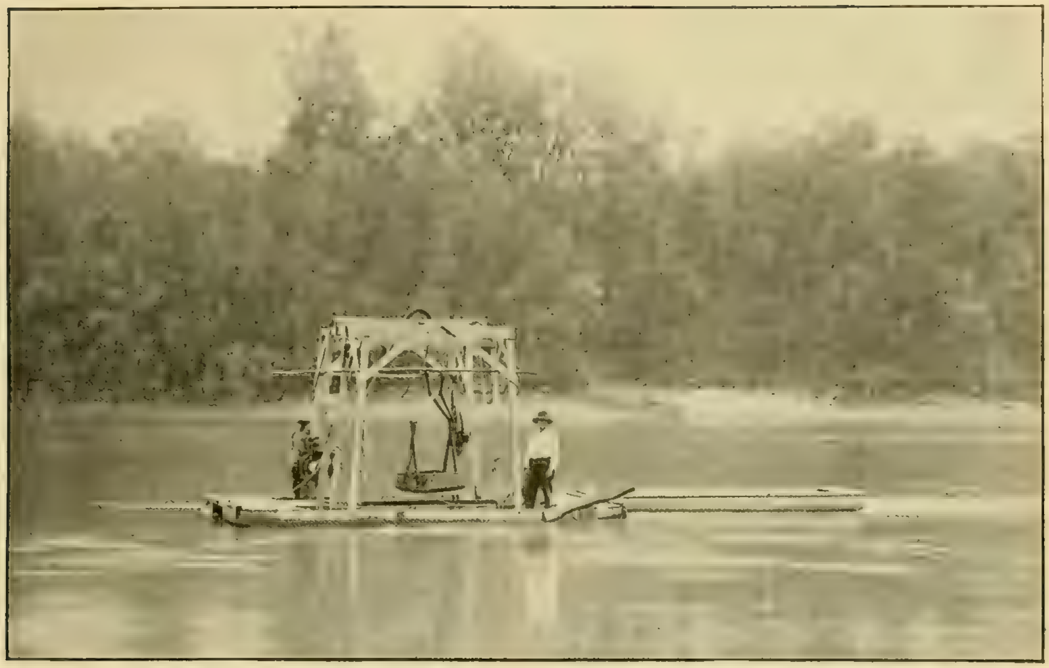

FIG. 1.—The dredge ready to be lowered into the water, Black River, Ark. (See p. 57.)

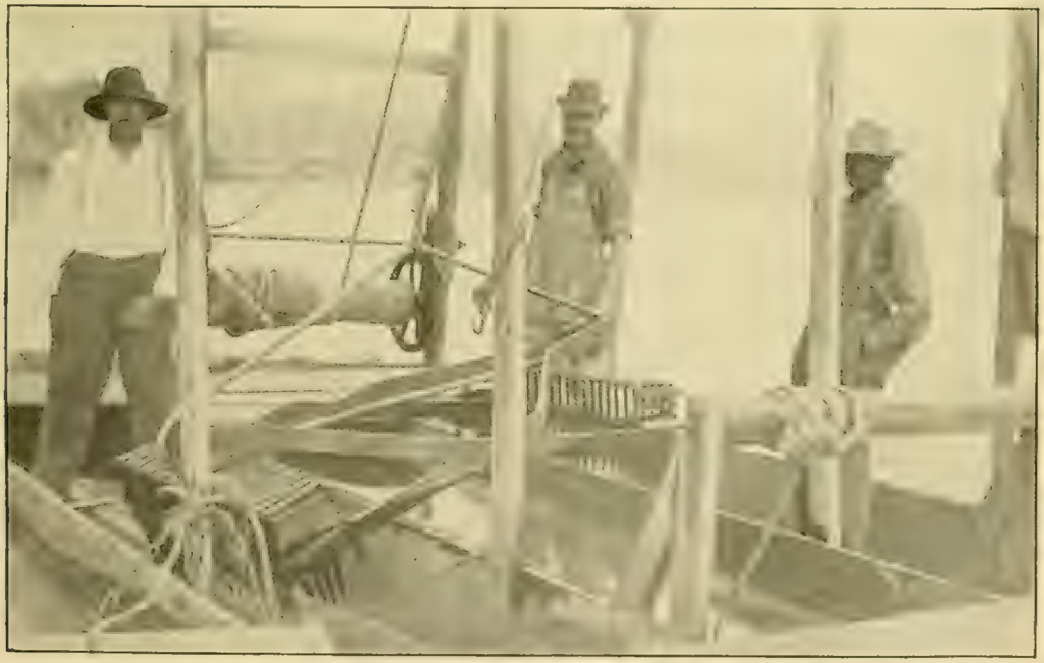

FIG. 2.—The dredge resting on gunwales of two boats forming the catamaran from which it is operated. (See p. 57.)

handles and working them together the forks are forced into the bottom and closed on the mussels. When it is closed, the handles are held together while the implement is raised hand over hand to the surface; after washing out the surplus mud and sand by a vertical motion the shells are dumped into the boat.

FORK.

Occasionally a common fork is used in the smaller streams, more especially during the low water of summer. The tool generally employed for this purpose is the coal or coke fork, such as is shown in figure 5. The manner of working with the fork is similar to that of spading a garden. The operator wades into the water from the shore or from his boat and begins to fork over the mussel bed systematically. On bringing each load to the surface of the river, the sand and mud are washed from the fork by dipping it a number of times into the water; the shells are thrown into the boat, which is always kept near by. Since it is much easier to go with the current, the shellers usually work downstream, and in consequence have more or less muddy water to contend with.

The method often yields good results, but involves more or less exposure to the water. It is not particularly to be commended, since the complete digging up of the beds is detrimental to the smaller mussels, as well as to the bed itself; the sand and mud of the bottom, to a certain extent at least, are carried away by the current to be deposited lower down in the river's course.

Since the fork can be employed only in very shallow water and during warm weather, its use is consequently limited and irregular. It may be found in use during low stages on the St. Francis River, Ark., the Wabash River near Vincennes, Ind., and in various isolated localities.

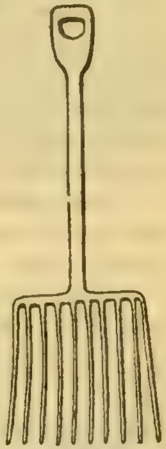

Fig. 5.—The fork used in taking fresh-water mussels in shallow water.

DREDGE.

The dip net is sometimes referred to as a dredge. There is also a typical mussel dredge that has been in limited use in Arkansas since 1912. While this dredge requires a greater initial outlay than the simpler forms of apparatus previously described, it offers much promise as a profitable method of taking mussels. The apparatus is well shown in the accompanying photographs (Pl. XXX, figs. 1 and 2) and requires but a brief description.

The dredges are of various dimensions; of the two particularly observed, one was 18 by 24 inches, the other 36 by 72 inches. The dredge may be described as composed of two heavy, long-toothed rakes with the iron handles so pivoted together scissors fashion that the two rakes when closed or brought together, form an oblong basket. Each half of the smaller dredge was 18 by 24 inches, the tines being 8 inches long and made of five-eighth inch square iron, pointed at the free ends. The remainder of the basket was made of flat iron about 1 inch wide. The dredge is operated between two boats firmly attached together by cross decking at the ends, but with a suitable space left between them.

In Plate XXX, the lower figure shows the larger dredge, 3 by 6 feet, spread, and held in this position by dogs on one side; it is resting across the boat. When the dredge is to be lowered, it is raised by the windlass until free of the boat, then swung around by hand to a fore-and-aft position (Pl. XXX, upper figure); it is then lowered into the water by unwinding the windlass. The line from the windlass passes through a block overhead (not shown in the picture) and down to the bridle of the dredge. The two pulleys through which the bridle passes should be noted on the ends of the dredge handles. When the brake on the windlass is thrown off, the dredge falls to the bottom, and the dog releases automatically. The dredge now rests on the bottom, covering a space 3 by 6 feet, with the tines of the two ends sticking into the substratum.

The first effect of turning the windlass, after taking up the slack, is to lift the ends of the handles and bring them together, thus causing the dredge to close. As the dredge closes, the tines thoroughly rake the bottom, and when completely closed every mussel and rock in the space covered, except those so small as to pass through the openings, are taken in the basket. Continued winding of the windlass brings the dredge out of the water, when it can be lowered into one of the boats and opened. All débris must be sorted out and thrown away. A small hand rake, like a flower rake, is used to clear the small stones which may have been wedged between the tines. In view of the contingency that the dredge may be fouled by a log or heavy stone, it is necessary to have a clearing line attached to one end of the dredge. A small windlass must be used to operate this line if the dredge is very heavy. The effect of hauling on this line is to open the dredge, which may have been partly closed, and bring it up to the surface; the haul is of course lost in such a case. Heavy dredges are more effective than the light ones.

The cost of the larger dredge was $65 complete, with boats and all; but there was very small expense for labor, as the work was done during the slack season and largely by the owner. The ordinary complete cost of such an outfit would be $100 or more.

If the openings between the tines are wide enough, the small shells will not be removed from the bottom. Comparing the dredge with the crowfoot drag, it may be noted that the latter takes mussels by chance and that repeated dragging over the same bottom is necessary to make an approximately clean catch, while the former makes a clean haul of only the mussels large enough to be taken. It will be seen, therefore, that the crowfoot apparatus, although less effective over a given small portion of bottom, is actually more destructive to the young mussels.

An entirely new form of dredge has recently been invented, which is operated by power and brings the mussels continuously from the bottom by means of an endless chain and buckets. No detailed description can be given at this time.

LOCAL MODIFICATIONS OF METHODS.

Various other forms of apparatus have been devised at different times and put into temporary use, but none of them seems to have won a place in the established methods of fishery. There are many local variations of the typical methods described, but it is not practicable to describe them all. Two special modifications of the use of the coke fork and of the basket rake were thus described as used in the James River in 1913:[a]

> The mussels [at Riverside, S. Dak.] were gathered with a coke or coal fork, having a piece of 2 by 4 lumber fastened to the handle, the length of this piece being according to the depth of the river. This fisherman had a novel way of anchoring his boat. At each end of the boat a hole was bored through the bottom large enough to insert a piece of 1.5-inch pipe, making a water-tight joint. These perpendicular

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[a] Coker, R. E., and Southall, J. B.: Mussel resources in tributaries of the upper Missouri River. Appendix IV, Report, U. S. Commissioner of Fisheries for 1914, 17 p., 1 pl., 1 map. Washington, 1915.

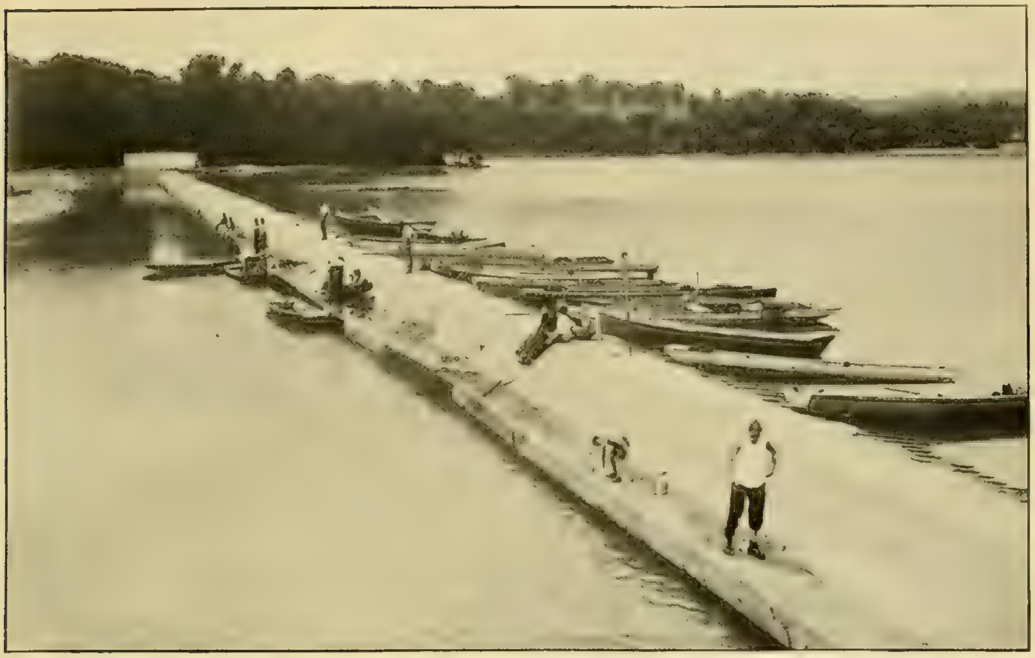

FIG. 1.—Mussel boats on Rock River Pool at Government locks, a few miles above the mouth of the river. The mussels are taken by hand while wading in the shoal water below the dam. (See p. 59.)

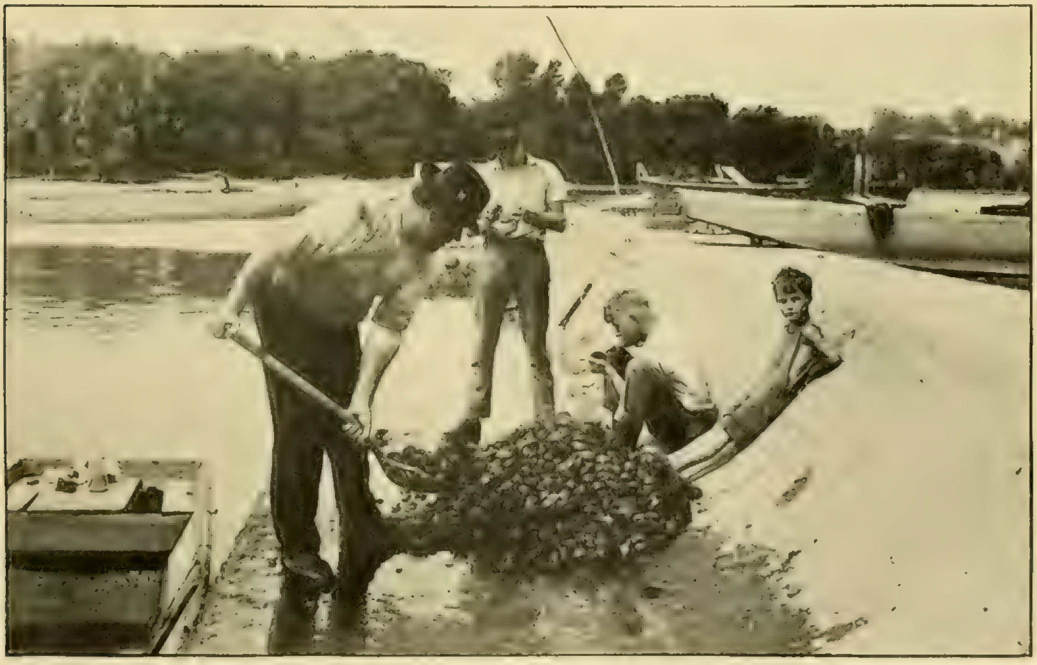

FIG. 2.—The mussels when taken are put into a small flatboat and conveyed to the dam, where they are transferred to another boat above the dam, as illustrated. In the second boat the mussels are taken to camp for cooking out. This is the scene of one of the most extensive mussel fisheries where shells are taken by hand. (See p. 59.)

pipes, rising to the level of the gunwales of the boat, served as sockets or sleeves, through which a long iron rod could be shoved into the soft mud bottom of the river. By anchoring in this way the boat was kept abreast of the current, while the fisherman used the sides as a fulcrum for the handle of the fork. After gathering all the mussels possible within reach he would pull up the rods, let the boat drift downstream a suitable distance, or beyond the portion of river just worked, and then anchor and resume operations as before.

At Milltown, mussels were gathered by means of the basket-rake dragged by a power-boat. The rake was peculiar in being without teeth but having a square brail made of 0.25 by 1.5 inch flat iron, to which was fastened a wire basket of 1-inch mesh. With each boat was a crew of four men, three to work with the rakes and one to operate the engine. One dragged the rake at the rear of the boat, while the other two worked at the sides. In this manner a strip of the river bottom 6 feet wide was thoroughly scraped.

SUMMARY OF METHODS OF FISHERY.

The principal forms of apparatus are the crowfoot bar, the dip net, the shoulder rake (or basket rake), the forks, and the dredge. A considerable quantity of shells, about 500 tons each year, are taken by hand. (Cf. Pl. XXXI.) The statistical reports previously cited (p. 39 above) show in detail the quantities of mussels taken by the several forms of apparatus. From these reports the percentages of the total of 51,571 tons of shells taken in the territory covered, as credited to the several forms of apparatus, may be computed and stated as follows:

	Per cent.		Per cent.
Crowfoot	70.0	Dip net	3.3
Forks	10.5	Dredge	1.2
Tongs	7.8	Rakes	1.2
Hand	5.3		
			99.3

SHORE EQUIPMENT AND PROCESSES.

It is customary for the shellers to establish camps alongshore. Sometimes the camps are individual and occupied by one sheller with his family; in other cases a sort of village camp is found where a dozen or more families of shellers are grouped. The selection of a site is governed, first, by the proximity of a good shell bed; next by the convenience to wood and shade. Rude frame buildings may be constructed, or tents may be used. A very common form of dwelling is the house-boat, or "shanty-boat," as it is generally termed (Pl. XXXII, fig. 2). There are many different forms and sizes of shanty-boats, to suit the needs and ideas of the fishermen; popular sizes are about 10 by 35 feet and 12 by 40 feet. With such boats it is a simple matter for the sheller to move from place to place, according to the requirements of the fishery. One or two small flatboats and usually a larger boat with a small gasoline engine are almost always employed, whether or not the house-boat is used.

After bringing the mussels ashore the soft parts must be removed. Where pearling is the exclusive object, each mussel may be opened with a knife inserted between the valves of the shell, so as to sever the adductor muscles; the meat is then cut out and examined for pearls. This may be done while wading in the river and the meat and shell thrown away at once. Such a process is entirely too slow and tedious for preparing shells for market; hence the cooking out process is exclusively employed in the shell fishery. The man may fish during the forenoon and cook out in the afternoon; in some cases the wife or children of the sheller attend to the cooking out, while the sheller continues the fishing operations.

The cooker consists of a vat about 5 feet long by 2 feet wide and from 12 to 18 inches deep (Pl. XXVII, fig. 2 extreme left, and Pl. XXIX, fig. 4). The frame may be of wood and the bottom of sheet iron or stovepipe iron, brought up a few inches over the lower edges of the wood to protect it from the fire. The bottom of the cooker is usually made to slope upward at one end in order to facilitate the forking out of the shells. The vat is set over a trench or ditched-out furnace, the back part of which is fitted with a couple of joints of stovepipe or smokestack of some kind to furnish the necessary draft; driftwood may serve as fuel.

When the cooker is filled with mussels, a small amount of water is added, and the whole is covered with burlap or gunny sacks. The fire is started in the furnace and continued until steam is being given off in quantities sufficient to kill the mussels, so that they will open readily. The process may take about 20 minutes or longer. If the mussel camp is situated near a factory or some establishment from which steam can be obtained at a reasonable price, there is a great saving in time and trouble by making a direct steam-pipe connection between the boiler and the cooker. The shells are prepared in the same way, but instead of applying heat beneath the cooker the steam is admitted directly into the container.

The shells are removed with a fork and thrown on the sorting table which is about 3 feet high and of sufficient width and length to hold at least one-half of the contents of the cooker. The mussels must be handled separately, picking or shaking out the meats, which are put to one side for later examination for pearls and slugs, while the shells are thrown into heaps on the ground or into small bins (Pls. XXVII, fig. 2, and XXXII, fig. 1).

When all the shells have been cleaned, the water, or soup, in the cooker is carefully strained through a small mesh screen of wire netting in order to recover any pearls or slugs which may have become disengaged from the meats during the cooking-out process. It is said that pearls which have lain on the hot metal bottom for any length of time are permanently injured. The size of the screen is usually about 1 foot square. Most of the pearls are found in the meats, which must be examined one by one. The pearls are not always visible, but are found by slipping the meats through the fingers. Small pearls are sometimes recovered by allowing the meats to rot in kegs or half-barrels. When reduced to a pulp, the mass is rubbed through a fine-mesh sieve, the pearls and slugs being retained on the sieve.

Many mussels are cooked out merely with the hope of finding pearls. The non-commercial shells must be thrown aside, but there is no general practice of classification of the salable shells. Often this is done by throwing shells of a certain quality, such as niggerheads, pimple-backs, etc., into one pile and blue-points, washboards, and miscellaneous shells into another. This is usually an advantage to the sheller, since he may obtain an advanced price on the best grade shells; yet the practice of buying the river run at one price is still very common. Most of the shellers do sort out the yellow sand-shells, since these command a price several times higher than the others; but even this is not always done, and thus a good many yellow sand-shells are received at the factories along with other shells. These, of course, are sorted out at the factory, and resold to

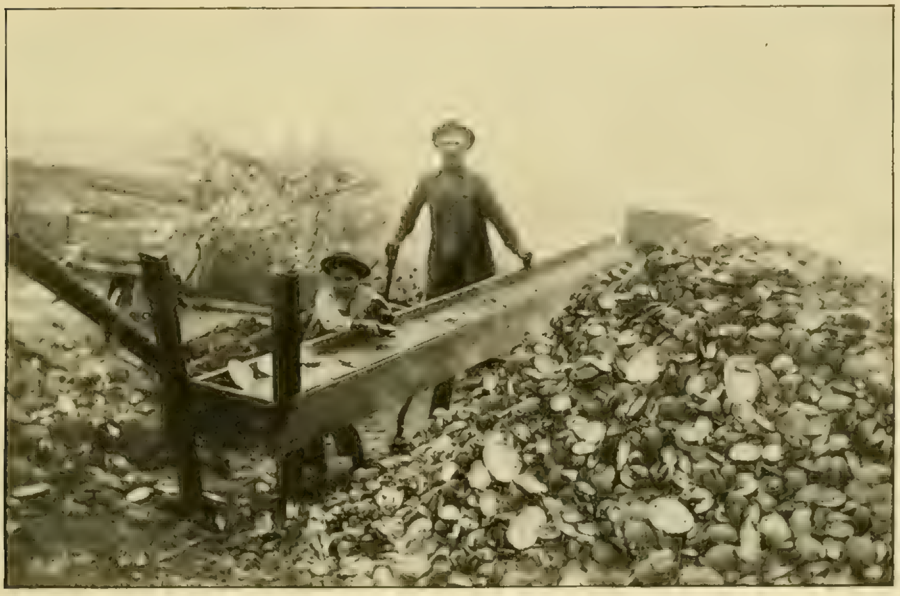

FIG. 1.—Sorting table and heap of shells on river bank. (See p. 60.)

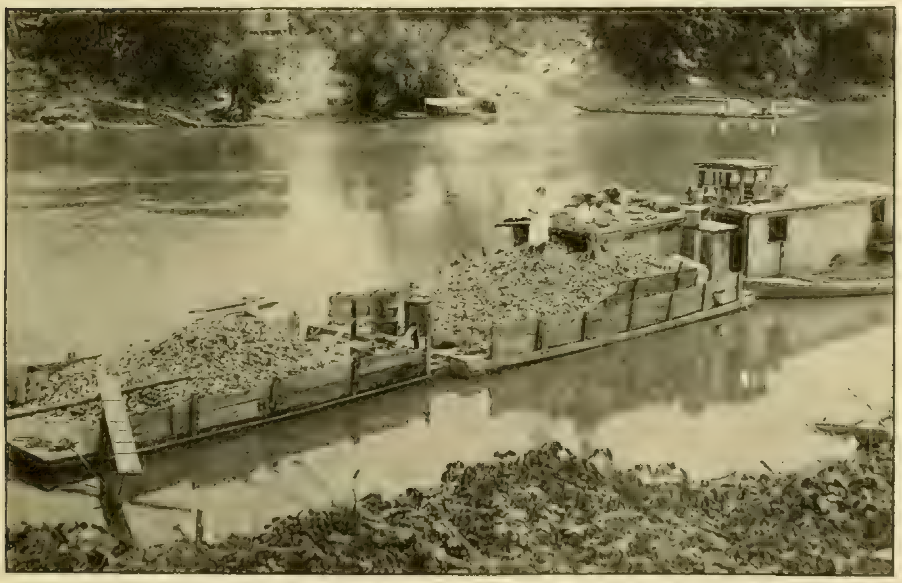

FIG. 2.—Barges loaded with shells and two shellers' house-boats, in Arkansas. (See p. 59.)

the export trade. It seems to be mere shortsightedness on the part of many shellers that prevents the effective classifying of materials before sale.

The shells are sometimes sold to local buyers or local factories; more often they are bought by traveling buyers who may be agents of the larger factories or professional shell merchants who buy in large quantities and sell as they find the most favorable market. Some buyers maintain large power boats and barges (Pl. XXXIII), which may travel up and down the river, prepared to load the shells and convey them to a convenient manufacturing or shipping point. The greater part of the shells are shipped by rail in car shipments from the nearest freight station. At times and in some places it has been the practice for shellers to operate small cutting plants, but the scheme has not always worked well in practice. Each is a profession in itself, and the best cutting is done by those who are practiced in cutting and shop management and who can keep well advised as to the market demand for the various sizes and qualities of blanks.

ELEMENTS OF WASTE.

CULLS.

The piles of culls are usually not large in proportion to the heaps of economic shells, but they include a good many kinds of shells, worthless because of excessive thinness, undesirable color, spotting, or other evident defect. Among such culls are the paper-shells, the pink heel-splitter, black sand-shells of pink nacre, purple warty-backs, and often the purple or salmon-colored elephant's ears and spikes. The last-mentioned can be used for making smoked-pearl buttons, although they are not usually in demand. It sometimes happens, therefore, that at the close of the season a buyer will take the usable colored shells at a reduced price. The tendency of shellers to throw in all off-colored shells has given unfortunate discouragement to this practice.

MEATS.

In connection with the shells collected each year, there are taken some 10,000 tons of wet meats for which there is no appropriate use. Small quantities are sold locally for use as fish bait with trot-lines, or hoop nets, or as food for poultry or pigs. The fresh meats, after being allowed to sour in the sun, are considered particularly good for these purposes; but generally only a small proportion of the meats has been so used. It is often a serious question in the mussel camp to make proper disposal of this material. The meats that can not be sold locally are often dumped into the river, buried in the ground, or put into a "rot box." The throwing of meats into the river in large quantities becomes objectionable when those that are not eaten by the fish and turtles rise to the surface in a state of decomposition and are washed ashore to cause an offensive stench in the neighborhood of the camps.

The meats, when dried in the sun or by the use of artificial heat, can be ground to make a fine meal, in which condition they appear to keep indefinitely. For the purpose of sun-drying they are spread on frames made of coarse-mesh wire screen so arranged that the air can circulate freely between them. In dry, sunny weather the meats can be dried in from 30 to 72 hours to about five-eighths of their wet weight. When so dried, they can be ground in a coffee mill or similar machine; but the foot part becomes exceedingly hard and tough when partially dried and rapidly wears out the mill. Since the meats are usually too large to feed into the coffee mill whole, they should be reduced by pounding or, better, by chopping in a meat chopper before drying. Sand should be avoided in the whole process, as it will damage the grinder. If the foot is to be ground, the whole meats must be dried by artificial heat to about one-seventh of the wet weight. This entails some additional expense for fuel and ovens. The loss of nutritive substance in discarding the foot is not great; but it is obvious that practical difficulties are encountered in separating the tough from the soft parts before grinding. The whole trouble arising from the toughness of the foot is obviated by putting the wet meats through a sausage grinder before drying and then regrinding the dried masses of meat in any suitable mill; the product thus obtained is not a fine meal, but a coarsely granular material, practically dust free and very suitable in form for use as food for poultry or fish. At the Fairport station the ground meats have been found to be very acceptable to chickens when moistened to make a mash and mixed with grain. Experiments made by the Bureau of Animal Industry show that the dried mussel meats are a suitable food for chickens, having about the same value as fish meal. To obtain like results, a slightly larger quantity of these substances than of meals made from the red meats must be used. For some years fresh mussel meats have been used as a food for fish at the station, and it has been found best to allow them to sour a little before feeding them. The ground dry meats have also been used in feeding small fish in aquaria and in ponds, and they have proven a very satisfactory food material. The ground mussel meats have recently appeared upon the market in the form of feed for poultry and fish.

The meats of the mussels could, perhaps, be used for human food if they were collected under sanitary conditions and properly prepared. This question should be subjected to experiment; but it would be obviously impossible to consider with reference to human food the use of meats saved as a by-product of the shell fishery under the conditions now prevailing.

Analysis of the mussel meats made for this Bureau by the Bureau of Chemistry indicates a very desirable content of protein, glycogen, phosphoric acid, and lime, if the meats are considered with reference to their use as a food for poultry or fish. Approximately the percentages are: Protein, 44 per cent; glycogen, 9 per cent; phosphoric acid, 9 per cent; and lime, 8 per cent. An analysis in detail of meats of fresh-water mussels from the Mississippi River is stated in the following table:

ANALYSIS OF DRY MUSSEL MEATS.[a]

	Per cent.
Water, at 65° in vacuo	7.59
Ether extract	2.84
Total nitrogen	7.11
Protein (N x 6.25)	44.44
Glycogen	9.35
Undetermined (nonnitrogenous organic material)	13.02
Ash	22.76
Ash content:	
Phosphoric acid, P_2O_5	39.31
Lime, CaO	34.71
Silica, SiO_2	15.86

Qualitatively, there were present in the ash small amounts of sodium, potassium, iron, magnesium, and a considerable amount of manganese. No copper or zinc was detected.

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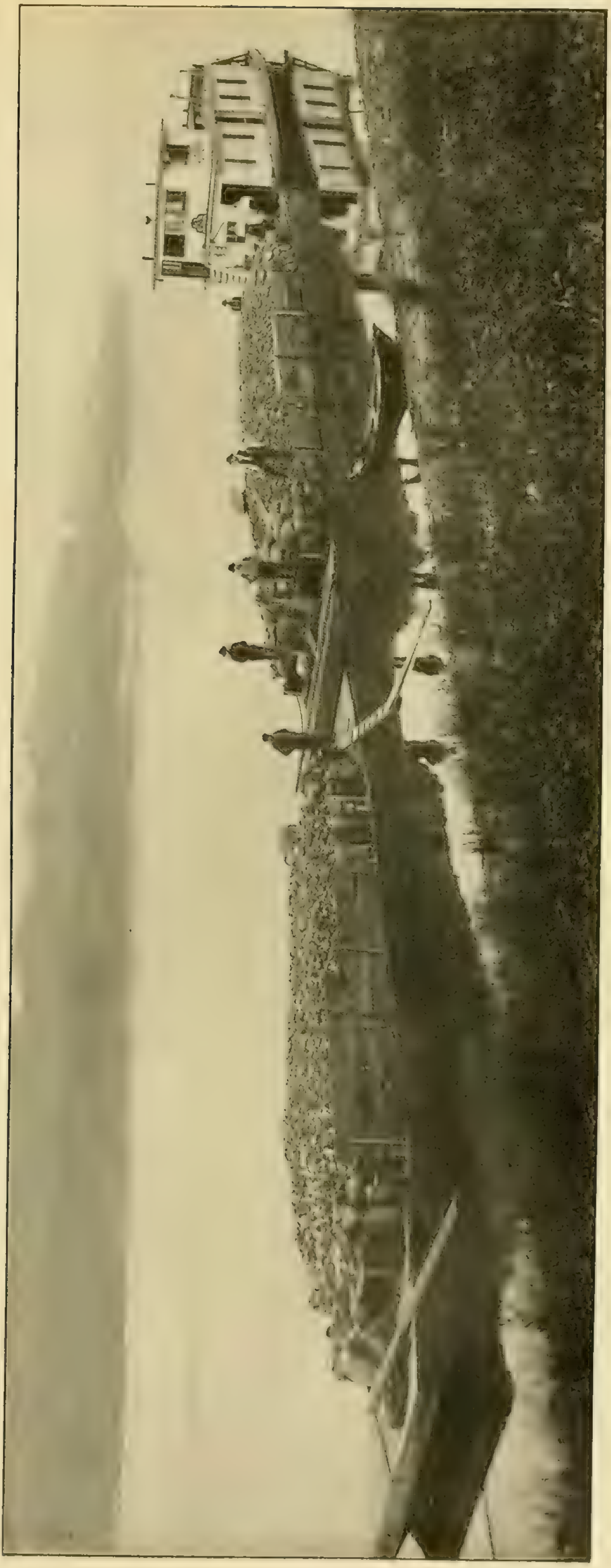
[a] The sample for analysis was from a lot of more than 100 pounds of ground, dry mussel meats, representing a collection of all of the ordinary species taken in the Mississippi River near Fairport, Iowa, and Lake City, Minn.



Buyer's power boat with barges of shells. (See p. 61.)

An article in the Journal of Biological Chemistry, 1910, volume 8, page 237, by H. C. Bradley, on "Manganese in the Tissues of Lower Animals" gives analyses showing the proportion of manganese in the ash as taken from a group of nine samples of mussels from the Mississippi River. The high proportion of manganese, as compared with its occurrence in other animal tissues, is of unusual interest, but is without economic significance as now understood.

Analysis of Mussels from the Mississippi River showing High Proportion of Manganese (After H. C. Bradley).

	Ash.	Manganese in ash.	Manganese in tissue.	Total nitrogen.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Maximum	23.5	3.5	0.823	7.37
Minimum	13.5	3.7	.500	7.37
Average	16.5	3.9	.63	7.24

UNDERSIZED SHELLS.

The most serious waste in connection with the mussel fishery consists in the taking and killing of undersized shells. It is argued by some fishermen that the young mussels should not be thrown back, since a considerable proportion of the mussels taken by the crowfoot die when returned to the water. Several experiments conducted at the Fairport Biological Station indicate that from 35 to 40 per cent of the mussels taken with the crowfoot and returned to the water die in a short time. However, careful counts of weights of shells actually taken in the mussel fishery and under 2 inches in greatest dimension show that it requires from 33,000 to 174,000 to make a ton, with an average of about 90,000. Should these mussels be returned to the water and should only one-third live to attain a size of 2 inches in greatest dimension, the surviving mussels would weigh much more than a ton, and would thus be of greater value to the fisherman than the entire original quantity marketed as small shells. They would yield a far greater number of buttons per ton, and thus would be of more value to the industry. Furthermore, the larger mussels would have spawned and taken part in replenishing the beds, and thus would have been of inestimably greater benefit to the conservation of the mussel beds.

Part 3. MANUFACTURE OF PEARL BUTTONS FROM FRESH-WATER MUSSEL SHELLS.

ESTABLISHMENT OF THE INDUSTRY.

Neither the manufacture of buttons nor the abundance of fresh-water mussels in the United States is an occurrence peculiar to recent years. Nevertheless it is strictly a modern development for the fresh-water shells to be the material for button manufacture in any important way; for the making of fresh-water pearl buttons, now the principal branch of the industry, dates only from 1891. Buttons of brass and wood have been made in this country since about 1750, buttons of metal since 1800, buttons of horn since 1812, buttons of marine shell since 1855, and buttons of composition since 1862. Meantime, mussel shells eminently suitable for button manufacture, and readily available, have grown abundantly in the streams of the Mississippi Basin through all historical times.

Long before an effective beginning was made, it seems to have occurred to various persons that the fresh-water mussel shells might be made useful for button manufacture. Indeed, there seems to have been an early industry on the Ohio River in the carving of cuff buttons from mussel shells more than 100 years ago.[a] As early as 1872, it is said, a man in Peoria, Ill., conceived the idea that the pearly shells of the Illinois River should have a value for manufacturing purposes, and he accordingly collected some of them and shipped them to Germany. It is very interesting to note that to this fugitive idea, resulting in a single small shipment, the actual establishment of the industry some 20 years later may perhaps be traced. However, it is evident that the matter was entirely abandoned for the time. According to local reports, a shipment of shells was sent from Beardstown, on the same river, to a factory in the East about 1876, but the material seems to have been considered impracticable of use. A more practical venture was made about 1883, when a commercial plant is reported to have been started at Knoxville, Tenn., where it was endeavored to make buttons and novelties from the shells of the Tennessee River. Unfortunately, the factory was discontinued after a short time, probably because of the lack of suitable machinery. It should be remarked that sometime in the late eighties pearl-button factories were in operation in Cincinnati, Ohio, and St. Paul, Minn., using as raw material the imported ocean-pearl shells. Although these plants were located on the very banks of good shell-bearing streams, there is no evidence that the river material was even experimented with.

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[a] Curiously enough, there is found in an early book of travels mention of a long-forgotten fresh-water button industry. The writer is indebted to Ernest Danglade for the reference. Dr. F. A. Michaux in 1802, under the auspices of the minister of the interior of France, made an extended tour for exploration in the United States, especially through that part lying west of the Alleghanies, or in the Ohio Valley. His record of a button industry on the Ohio River is now of rare interest. He observes (translating from the French): "In the Ohio, as well as in the Alleghany, the Monongahela, and the other rivers of the West, there is found in abundance a species of mussel having a length from 2 to 5 inches. It is not eaten at all, but the nacre, which is thick, is used to make cuff (or sleeve) buttons. I have seen some of them at Lexington, Ky, which were equal in beauty to those used in Europe. This new species, which I have brought back, has been designated, by citizen Bosc, under the name of *Unio ohiotensis.*"

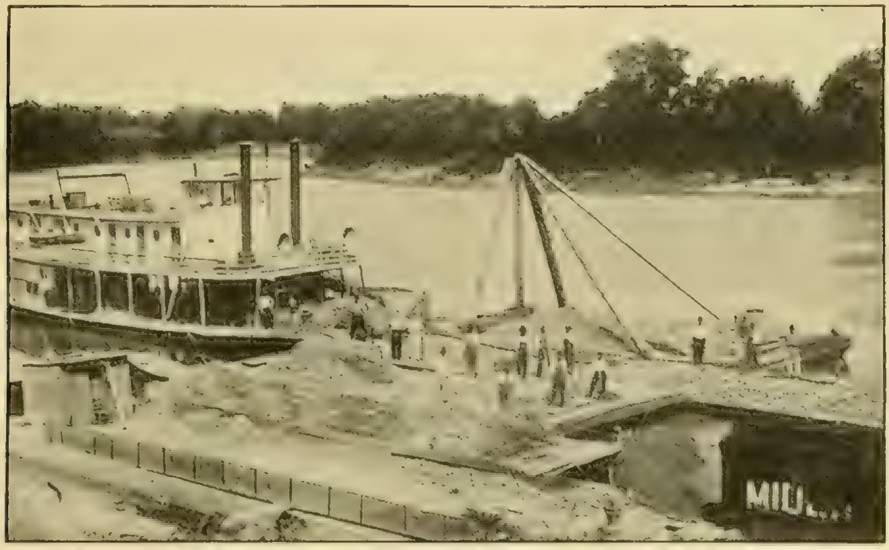

FIG. 1.—Receiving shells at boat landing. (See p. 61.)

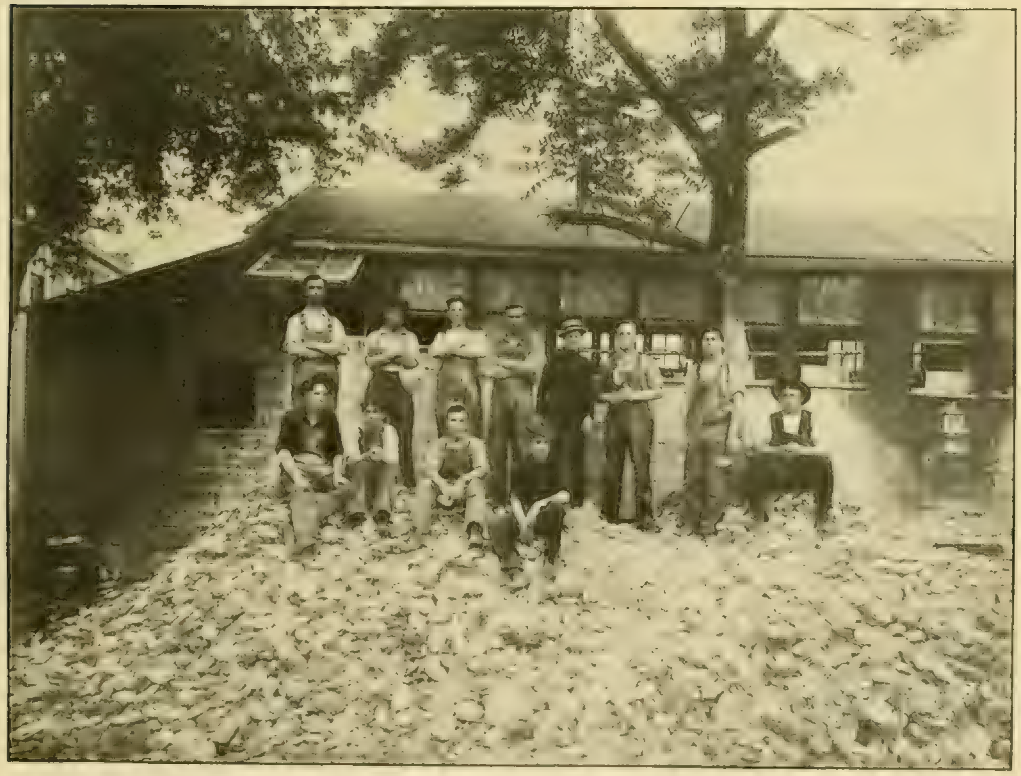

FIG. 2.—Small cutting plant and operatives on Mississippi River. (See p. 72.)

It must be said, in explanation of the seemingly half-hearted endeavors and repeated failures, that the use of any form of pearl for button making was not widely practiced in the United States, and that, in the countries where the manufacture was principally pursued, fresh-water shells of suitable quality were quite unknown. Furthermore, the river shell is quite distinct from ocean pearl in its qualities, so that the same machinery and methods, as experience has proven, can not well be applied to both kinds of shell.

For the practical initiation of the fresh-water pearl-button industry credit must be given to the late J. F. Boepple, a man of singular tenacity of purpose, indefatigable and unyielding by nature. His characteristics did not adapt him for commercial success, but they did enable him to battle against the varied obstacles that would have overwhelmed a weaker or less persistent character. By its conception and practical initiation, the fresh-water pearl-button industry is Boepple's; by its development and elevation to the plane of an important national industry it is the product of other resolute persons, who persisted through the period of threatened failures to compel the adaptation of the industry to the requirements of business efficiency.

Mr. Boepple was a turner and button worker in Ottensen, Germany, near Hamburg, when a friend and fellow worker brought to the shop a box of shells of a kind entirely unfamiliar to them.[a] He said that they had been shipped to his father from America a good many years before, but did not know from what place they came, except that they were taken from a river "somewhere about 200 miles southwest of Chicago." After some experimentation at odd times it was concluded that these mussel shells would be good for making buttons. In the following year Mr. Boepple sold his business and, taking with him a turning-lathe equipment and some other trade tools, embarked for America, where he landed in March, 1887. He first engaged in farm work near Gibson City, Ill., and a little later, July, 1887, stopped at Petersburg, Ill., on the Sangamon River. He says, "While in bathing one day my foot was cut, and upon examination of the cause I found the bottom of the river covered with mussel shells." The vivid picture of the situation which confronted the young immigrant is given by his own words: "At last I found what I had been looking for; yet there still was a problem before me. I was without capital in a strange land among strange people and unfamiliar with the language."

The next few years he spent in farm work and railroad-construction labor; but during this time he located other shell beds, in the Rock River near Rock Island, Ill., in the Mississippi near Muscatine, Iowa, and in the Iowa River near Columbus Junction. At the last-mentioned place, having formed a shop, partly with equipment he had brought from Germany, he engaged after work hours and during the winter in making shell novelties, such as pins, bridle buttons and cuff buttons, for which he found a sale. (See Plate XXXVI, fig. 1.)

Learning later that the price of buttons was becoming higher, he went to Muscatine, where he enlisted the financial and mechanical assistance of William Molis and R. Kerr, and there the first button factory was launched in the early part of 1891.

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[a] The following account of the beginning of the industry is based on a statement written by Mr. Boepple at the request of the director of the Fairport station. It was the recollection of Mr. Boepple that the shells experimented with at Ottensen were muckets and three-ridges, and it is presumed that these are the shells shipped by Wm. Salter from Peoria, Ill., in 1872.

This factory and a following one did not succeed against the inevitable difficulties confronting a new venture. Better success was had in the ensuing year, when a market for the product began to be found, but it was hardly before 1895, after several factories in the hands of various parties were in operation, that the industry could be said to be fairly established.[a]

The greatest expansion occurred in 1897 and 1898, when a condition of more than local excitement prevailed. Thus, in 1897 there were 13 button or blank establishments in 4 cities on the Mississippi River, while in 1898 there were 49 plants in 13 towns on the same river, besides at least 12 factories in as many different cities more or less remote from the Mississippi River. The territory of the new industry now extended from Omaha, Nebr., to Janesville, Wis., and Cincinnati, Ohio, with the center still at Muscatine, Iowa, where there were 28 blank-cutting plants, or "saw works," as they were then called, and 5 complete factories.

The next great advance came in 1901 with the invention of automatic facing and drilling machines; by subsequent invention (1903) these machines were combined into one, the automatic facing and drilling machine. Both the single and the double machines are still in use, although improved by many minor changes and additions. These machines are very ingenious in design, and not only enable an operator to turn out four or five times as great a number of buttons per day, as compared with the product of the foot-power lathes formerly in use, but also insure a greater uniformity of finish.

SOME ECONOMIC EFFECTS OF THE INDUSTRY.

DEVELOPMENT OF THE INDUSTRY.

Recent as the establishment of the industry is, the effects have already been noteworthy. The United States Census reports show that in 1849, before pearl material was in use, the value of American button products was $964,000, and in 1859 $949,000. The manufacture of ocean-pearl buttons and of composition buttons began about this time, or in 1855 and 1862, respectively, and perhaps it is due to this that in 1869 we find the value of all button products amounting to $1,779,000 and in 1879 to $4,450,000. No increase is shown in the next decade, for in 1889 the value was but $4,127,000. It was during the two following decades that the fresh-water button industry developed with such rapidity. The value of the button product of the country in 1899 was $7,696,000, in 1904 $11,134,000, and in 1909 $22,708,000.[b]

It is unfortunate that the figures for pearl-button manufacture alone are not available for other years (prior to 1914) than 1900 and 1905, but from the reports of these years we find that the fresh-water pearl-button product was valued in 1899 at $2,766,053 and in 1904 at $4,370,241. Between these two dates the first automatic machinery was put into use. During the same period the output of ocean-pearl buttons fell from nearly $2,000,000 to about $1,500,000 in value. It will not appear, however, from facts given below that the great development of the fresh-water pearl manufacture has caused any general decline in the other branches of the industry. The census taken for 1909 gives no classification from which data can be obtained regarding pearl materials; but from a statistical survey which the Bureau of Fisheries conducted for the year 1912[a] it is ascertained that the value of the button product from fresh-water shells alone amounted to $6,173,486, with blanks for sale amounting to $2,511,217, and by-products with a value of $187,607. As reported by the Census Bureau's summary concerning the button industry for 1914, fresh-water pearl buttons, exclusive of blanks and by-products, were valued at $4,879,844.

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[a] It should be recorded that Mr. Boepple, who subsequently removed to Davenport, Iowa, and later to Cannelton, Ind., continued to engage actively in the button industry until February, 1910. At that time he became shell expert of the Fisheries Biological Station at Fairport, Iowa, where he rendered invaluable service until his death in January, 1912.

[b] Exclusive of buttons manufactured as by-products of other establishments not engaged primarily in button manufacture. All the figures above are reduced to even thousands for convenience of examination.

DEVELOPMENT RELATIVE TO OTHER BRANCHES OF THE BUTTON INDUSTRY.

Fresh-water pearl has gradually come to assume first place among materials for button manufacture, as shown by a table herewith. The principal materials are fresh-water pearl, ocean pearl, metal, vegetable ivory, celluloid, cloth, bone, and miscellaneous materials elsewhere listed.

RELATIVE RANK OF FRESH-WATER PEARL AMONG THE DIFFERENT MATERIALS EMPLOYED FOR BUTTON MANUFACTURE AT VARIOUS DATES.

Material.	1889	1899	1904	1909	[a] 1912	1914
Buttons, total		$6,467,373	[b] $9,040,029	(c)		$16,233,198
Fresh-water pearl	(d)	1,176,285	3,359,167	(c)	$6,173,486	4,879,844
Ocean pearl		1,951,558	1,511,107	(c)		2,489,364
Metal		887,521	1,312,741	(c)		763,287
Vegetable ivory		1,144,677	1,305,766	(c)		2,885,503
Cloth		468,121	766,091	(c)		
Bone		137,401	124,454	(c)		329,934
All others [e]		701,810	660,703	(c)		4,885,266
Button blanks made for sale		656,036	[f] 916,003	(c)	2,511,217	
All other products			[g] 1,177,737	(c)	137,607	
Aggregate	$4,216,795	7,695,910	[b] 11,133,769	[b] $22,708,065		[h] 20,791,985

[a] Fresh water only.

[b] Exclusive of buttons to the value of more than $1,000,000, made in each year 1904 and 1909 by establishments engaged primarily in the manufacture of other products.

[c] Not classified.

[d] The product of Iowa and Illinois in 1897 was $243,655 and in 1898 $252,570 (Smith).

[e] Some of the materials from which buttons are made, in addition to those indicated in the table, are brass, composition (clay, etc.), wood, glass, gold, hoof, iron, ivory, leather, paperboard, porcelain, silver, steel, and also, in some cases, skim milk (casein), animal blood, and probably bakelite.

[f] Probably fresh-water pearl chiefly.

[g] Partly fresh-water pearl products.

[h] Includes blanks, or molds, snap fasteners, and all other products in amount, $4,558,787.

The census report of 1900 states: "In 1890 there was not a single fresh-water pearl button made in the United States. In 1900 the making of these buttons constituted the second most important branch of the button industry." Yet, at the next census, only five years later, the fresh-water pearl buttons are found not only in the first rank, but actually exceeding in value the combined product of the two next highest—ocean pearl and vegetable ivory.[b]

It would be of value to compare the production in gross of buttons and the price per gross during the years from 1899 to 1909. Unfortunately, the census report gives no classification except for the years 1899, 1904, and 1914; but the table following supplies the blanks by computation, the basis for each computation being explained in footnotes.

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[a] It is well known that for several reasons there was a temporary decline of button manufacture between 1909 and 1912.

[b] The figures for 1914 are not quite representative for the fresh-water industry, since the blanks and by-products aggregated at the bottom of the table are probably principally fresh-water products, as may be inferred from the total for that industry given by the census report in another place as $4,370,000.

Year.	Source.	All kinds.		Fresh-water pearl.		Ocean pearl.	
		Million gross.	Price per gross.	Million gross.	Price per gross.	Million gross.	Price per gross.
1889	Estimate	[a] 14.0	....	([b])	....	([c])	....
1899	Census	21.3	$0.30	4.3	$0.27	4.0	$0.48
1904	do	29.9	.30	11.4	.30	1.7	.87
1909	Estimate	[d] 66.0	....	[e] 30.0	[e] .235	....	....
1912	Bureau of Fisheries	....	....	[f] 26.0	[f] .236	....	....
1914	Census	60.6	....	21.7	.225	4.5	.551

[a] Obtained by dividing census value of $4,217,000 by assumed average price of 30 cents per gross.

[b] None.

[c] Unknown.

[d] Obtained by dividing census value of $22,708,000 (aggregate), reduced to $20,000,000 to allow for value of waste products, by assumed average price per gross of 30 cents. This average price taken from censuses of 1900 and 1905.

[e] Unofficial estimate.

[f] From statistical survey of the fresh-water mussel industry conducted in 1913 by the Bureau of Fisheries.

IMPORTS AND EXPORTS OF BUTTONS.

The history of imports of buttons of all kinds since 1891 has an interest in connection with the domestic industries and is shown in an accompanying table. The exports of domestic buttons are also shown for the few years for which they have been separately shown in the schedule. (See table below.) We find, first, a substantial decline in imports approximately coincident with the inauguration of the fresh-water pearl industry, but evidently not related thereto, this decline being attributable to the financial stringency of 1892–1894; second, a substantial recovery of import trade in 1895 and 1896; third, a marked decline in imports coincident with the rapid expansion of the fresh-water pearl-button industry in 1897 and the following years; fourth, a general slow rise in the amount of importations, beginning about 1900, although never, until 1913, rising to more than about one-half of the importations of 1891. Nevertheless, the difference in value between the imports of 1891 and 1910 is not at all commensurate with the output of the fresh-water pearl industry. In the later years there is not a wide difference between the value of imports and exports. Imports of pearl buttons have never been of considerable value, except about 1896, 1903, and 1917.

IMPORTS AND EXPORTS OF BUTTONS.[a]

Year ending June 30—	Imports, all kinds (dutiable).[b]	Exports, all kinds.	Imports (for consumption) of pearl and shell buttons, including imports from Philippines.	Year ending June 30—	Imports, all kinds (dutiable).[b]	Exports, all kinds.	Imports (for consumption) of pearl and shell buttons, including imports from Philippines.
1891	$2,096,000	....	$100,000	1905	$866,000	....	$172,000
1892	1,317,000	....	292,000	1906	873,000	....	134,000
1893	1,410,000	....	275,000	1907	936,000	....	164,000
1894	465,000	....	38,000	1908	653,000	....	93,000
1895	1,071,000	....	376,000	1909	767,000	....	87,000
1896	1,424,000	....	332,000	1910	1,056,000	$474,000	107,000
1897	950,000	....	259,000	1911	762,000	557,000	100,000
1898	436,000	....	37,000	1912	1,130,000	724,000	71,000
1899	451,000	....	24,000	1913	1,856,000	849,000	137,000
1900	593,000	....	36,000	1914	2,082,000	654,000	253,000
1901	551,000	....	76,000	1915	1,005,000	1,171,000	280,000
1902	954,000	....	424,000	1916	789,000	1,903,000	546,000
1903	1,190,000	....	469,000	1917	1,207,000	1,982,000	1,058,000
1904	893,000	....	157,000	1918	1,276,000	[c] 2,105,000	914,000

[a] From Government reports and information furnished by the U. S. Bureau of Foreign and Domestic Commerce, but in each case reduced to the nearest even thousand.

[b] Imported buttons of high price are principally glass, pearl, and metal; of medium price, Philippine pearl (small quality); of low price, agate, bone, and nickel bar and recently Japanese pearl.

[c] Including pearl buttons to the value of $600,666.

When the imports are added to the domestic production we observe the enormous increase (in consumption) from about $9,000,000 to about $23,000,000, during the course of 20 years, an increase entirely disproportionate to the growth in population during the same period. The per capita consumption of buttons grew from about 37 in 1891 to about 106 in 1910.[a]

This magnified consumption can not be attributed simply to increased prosperity or to growing extravagance. It is a matter of common experience that where relatively expensive buttons were formerly hoarded and used again and again, the modern cheapness of good material has lead to the general abandonment of this laborious practice. The real significance of the fresh-water pearl industry is that it has, by its direct and indirect effects, made good buttons low in price and more generally used; as, indeed, would be the result in any industry that found a new and abundant resource to yield a quality of product formerly obtainable only from less available and more expensive materials.

During the last few years there has been increasing activity in various branches of the button industry, notably in vegetable ivory and celluloid, but fresh-water pearl still ranks as the paramount material used by button manufacturers.

SUMMARY OF ECONOMIC EFFECTS.

We may thus summarize the broader effects attributable in large part, though we would not say exclusively, to the development of the fresh-water mussel industry. Although affording employment to many wage earners and giving occasion for an important fishery, it has not caused a material diminution, if any, in the output of any other branch of the button industry. The fresh-water pearl product alone is now greater than the entire output of the button industry in 1890; but at the same time the product of other branches of the industry is greater than in 1890. The fresh-water product is simply an addition by so much to the available wealth of the country. It has made a good button almost universally available, so that the total consumption has been greatly augmented. The economic rating of this industry will always depend in considerable measure upon its supplying a good product at a relatively low price; and this condition will be maintained only by preventing the depletion of the native resources and by promoting economy in manufacture.

DEVELOPMENT OF MODERN METHODS.

In the early stages of the industry the making of buttons was accomplished largely by hand machinery, so-called. The shells were held against the revolving saws by hand while the blanks were being cut out. Each blank was held with the finger against a revolving emery wheel, first to be backed, or ground to a smooth surface, and next to be turned or faced to a proper form with the central depression worked out. Then the blanks individually were placed in chucks for the drilling of two or four holes. Only the final polish was administered to the buttons in bulk. Sorting and carding was, of course, done by hand.

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[a] These figures are based on the computation that the $4,216,000 worth of buttons of 1890 represented, at 30 cents per gross, 14,000,000 gross, or 2,000,000,000 buttons, while the output in 1910 is computed in the same way as 9,500,000,000. Importations are added and exportations deducted.

Most of these processes have become obsolete in the United States with the development of modern machinery. It is, indeed, to the automatic machinery that the industry owes its present relative importance. The old process of sawing remains practically unchanged, but the grinding, facing, and drilling, the principal features of button making, are accomplished by automatic machinery. For the three processes either two or three machines are used; in some cases a grinder attachment to the double automatic makes it possible to combine the entire process in one machine.

The sorting, or grading, of the buttons requires nice judgment and must still remain a hand process; but recently a machine has been introduced for the attachment of buttons to the cards.

Not only the departures in the mechanical equipment but the improved efficiency of labor and better shop management are combining to increase the output and to promote economy of production with better quality and uniformity of product. These, and such other present-day features as the utilization of waste materials and the introduction of sanitary devices, will undoubtedly be more generally and effectively applied in the future.

PROCESSES OF MANUFACTURE.

The description of the general process of button making as given below is essentially that of the average modern plant, although in each factory characteristic modifications of method are encountered.

PREPARATION OF SHELLS.

Storage.—When the mussel shells are received by barge or freight car, they are hauled to large covered or exposed storage bins at the factories, to be kept until ready for use. A rough sorting is often done at this stage, so that each bin will contain shells of a relatively uniform size and quality. There is no apparent deterioration of the quality of shells if protected from the weather. If not so protected, they are liable in time to lose the luster and become lifeless or chalky. The exterior of the shell is most readily affected once the horny covering is worn or scaled off. For this reason shells which have been long exposed on the banks or "dead" shells from the rivers are considered undesirable.

Classifying—When the shells are taken from the bins for use, they are first sorted by hand according to species or quality of material, if this has not previously been done, and are then classified as to size. The latter process is accomplished by a machine called a classifier, which, though larger, is similar in principle to the classifier used for blanks (Pl. XXXVIII, fig. 1). The shells are put into a large hopper, from which automatically they are fed slowly onto an endless belt leading to the classifier, which consists, primarily, of two hollow metal rollers about 6 inches in diameter and 8 feet in length. By falling between the two rollers the shells are to be separated, roughly, into four or five grades, according to size and thickness. To this end the rollers are set with an incline and are not quite parallel with each other, being more widely separated at the lower ends. As they revolve outwardly the shells slip, or roll down the incline to a point where the opening between the rollers permits them to fall into one of a series of buckets placed below. The smaller and thinner shells are found in the buckets nearest the head.

The classification of shells by size and character has obvious advantages for adaptation of material to particular grades of buttons and to uniform speeds of machinery.

SOAKING.—After classifying, the shells are placed into large metal tanks or vats, each holding about a ton, or sometimes into barrels. The containers are then filled with water, in which the shells are allowed to soak for a week or more. The process is intended to soften the material, which would otherwise be too hard on the saws, as well as so brittle as to chip and yield blanks with rough edges. The smaller sizes of shell may simply be put into damp cellars, sprinkled, and covered with wet cloths.

Curiously enough, there is a difference of opinion among manufacturers as to the merits of this treatment, the contrary view being held by some that the material works better if not soaked, but simply sprinkled, before cutting. The custom of soaking is one that is generally desired by the cutters, however, since it is held to lessen the labor of resharpening the saws.

An obvious but probably unnecessary disadvantage of the soaking process consists in the fact that the shells as marketed have small bits of meat attached, so that after soaking the water may become more or less foul. In handling the shells scooped from the vats there is the possibility of contamination in the event of abrasions upon the hand. This is undoubtedly the cause of an infection to which cutters are more or less liable. The addition of an antiseptic compound to the water of the vats should be a universal feature of this process.

SAWING OR BLANK CUTTING.

THE MACHINE.—The cutting machine is essentially a lathe fitted, on the one hand, with a tubular saw of the necessary diameter to obtain the required size of button, and, on the other hand, with a wooden plug and a ratchet handle or lever for gradually forcing the rough shell against the rapidly rotating saw (Pl. XXXV, fig. 3). The shell is held in position either by tongs or by the hand protected with a mitten. During the cutting process small jets of water are directed against the shell to keep it, as well as the saw, cool and also to prevent the production of troublesome and injurious dust (Pl. XXXVIII, fig. 2). Successive blanks as they are cut are crowded through the tubular saw to fall into a receptacle below. When the desired blanks are removed, the shell is thrown into a bucket or box to be subsequently dumped upon the shell heap, unless the shell is to be passed to another machine for a second cutting of smaller and thinner blanks. The cutting machine, including the saw, is about the only one of the many used in button factories on which no radical improvements have been made since it was first introduced and adapted to the fresh-water shells. The original invention may or may not be the best solution of the problem, but as yet none of the machines put forth as improvements has earned an established place in manufacture.

The saws must be made of specially hardened steel, and are obtainable from only a few shops. When received from the factory, each saw is simply a rolled cylinder tapering at one end, being without teeth at this stage (Pl. XXXVII, fig. 1). They are made of different tempers as extra-hard, hard, regular, soft, and very soft, for adaptation to the varied texture of the material to be cut.

The sizes of the buttons are determined by the inner diameter of the cutting end of the saw, and the unit of button measure is one-fortieth of an inch, called a line. Buttons from fresh-water shells vary in size from 14 to 40 lines (from about one-third of an inch to 1 inch). Buttons of ocean pearl are sometimes made as small as one-fourth of an inch, and the same size of fresh-water buttons is made in novelty works as well as the larger sizes up to 60 lines (1.5 inches) or larger.

The button-cutting machine is equipped with a three-step cone pulley so that the speed may be adapted to the shell and line to be cut. For blanks of 14 to 20 lines a speed of over 400 revolutions per minute may be used, while about 275 revolutions would be used for 22 to 36 lines. The largest sizes, 36 to 60 lines, would be cut with a speed of only about 180 revolutions per minute. The speed will, of course, be adapted somewhat to the shell and to the whim of the individual operator.

The cost of a cutting machine installed was estimated four years ago at about $24. (See page 44.) The number of machines operated in one plant varies from three or four in small blank-cutting shops to one hundred or more in larger factories.

DETACHED CUTTING PLANTS.—While button factories commonly include cutting rooms (Pl. XXXVIII, fig. 2), where the blanks, or buttons in the rough, are cut from the shells, there are yet a good many establishments devoted exclusively to the finishing and grading. In such cases the cutting is done in detached cutting plants (Pl. XXXIV, fig. 2), which may be located at convenient points in different States and from which the blanks may be shipped to the factory. There are also numbers of independent cutting plants, or button shops, which may be more or less portable. The owners of such plants take the shells from the river or buy them and cut out the blanks, which are then sold to the manufacturers of buttons. It has frequently occurred that when a new region of abundance of commercial shells has been discovered numerous small cutting plants have sprung up along the banks or on house-boats. A single fisherman may purchase and install a single machine and small gasoline engine to cut the shells that he and his family take, or a number of machines may be installed, labor employed, and the product of other fishermen purchased. In a few cases the cutting plants are cooperative, a number of shellers operating each a particular machine and cutting and marketing his own blanks. The blanks may be sold to the owner of the machines or in the open market.

Most manufacturers purchase blanks when it is more profitable to do so than to produce them in the factory; but generally a manufacturer prefers to produce his own blanks, since greater care can be exercised in proper cutting. There are cases where the independent cutting plants are particularly to be recommended, as where the shells are too scattering for convenient shipment in carload lots, or, in remote localities, whence the freight charges on the bulky shells are practically prohibitive. In some streams it appears that the best solution of the marketing problem would be had by the operation of small cutting plants on house-boats, which can be floated down the river, cutting the shells as they are found and throwing the waste shell back into the river. The blanks can be shipped from time to time from convenient points. This plan has also its advantages where the shells are abundant but so spotted or stained that the proportion of good shell to waste is relatively low. It is of interest to note that the freight charges paid for transportation of shells and blanks in 1912 were reported at $131,000.

WORK AND WAGE OF CUTTER.—The cutters are men. Each cutter is ordinarily expected to provide himself with a few tools, such as three to five saw spuns, a button-cutter's hammer, shell tongs, saw, files, and hose and bibb. This equipment may be purchased either from the factory or elsewhere; its cost in prewar times was about $2 and approximately $4 in 1919.

The button cutter, having had his shells weighed out to him and having received his saw, proceeds to fit the saw into the spun, or saw holder, and then sets the spun in the chuck fixed in the machine, which is thrown into operation to test if the saw is set perfectly true. If not found to be running true, adjustment is effected by tapping, or by refitting. It may require several minutes, at least, to obtain a correct adjustment. With a slender three-cornered file the teeth (11 to 20 or more in number, according to the size of blank to be cut) are then cut into the saw, after which the teeth are set, and the machine is ready for practical work. (See Pl. XXXVII, fig. 1.) In quantity of production, quality, and economy, as will be more fully shown later, much depends upon the skill and interest of the cutter, as well as upon the good judgment of the manufacturer in the purchase and assignment of material.

Roughly speaking, a cutter may use about 100 pounds of shell per day, cutting 25 gross or more of blanks. The number of pounds of shell required to produce a gross of buttons varies with the line, the character of the shell, the skill and interest of the cutter, and with the care of the management.

Once a week the cutters take their blanks to the foreman and are paid at a given price per gross. There is usually some system by which the cutter is held responsible for excessive waste of shell. The wages of cutters vary widely, according to the skill and regularity of the individual.

Since the number of gross is computed from the weight of the blanks in bulk, it is customary to give the blanks a preliminary shaking over sieves adapted to the size to be used. The openings in the sieve are just a little smaller than the blanks, so that, not only the chips and dust are removed, but also such imperfect blanks as have one diameter less than that of the opening.

Representative prices in 1914 and in 1919 (figures in parentheses) were as follows:

6 (7½) cents per gross of 14 lines.
6 (8) cents per gross of 16 lines.
7 (8½) cents per gross of 18 lines.
8 (9½) cents per gross of 20 lines.
9 (10½) cents per gross of 22 lines.
10 (11½) cents per gross of 24 lines.
13 (15) cents per gross of 30 lines.
17 (18) cents per gross of 36 lines.
21 (26) cents per gross of 40 lines.

At these prices a cutter could earn from $10 to $20 per week in 1914, or from $12 to $35 in 1919. A small bonus may be paid for full-time work.

Production of Blanks.—With good cutting of niggerhead shells 100 pounds of shell will yield 12 to 14 pounds of blanks, but the production is usually much lower, often only about 9 pounds. A fine grade of muckets from Lake Pepin, being light and of comparatively uniform thickness, will yield 20 pounds of blanks per 100 pounds of shell.

The table following prepared by the shell expert of the Fairport station is of interest as illustrating how the different species and sizes of shells may be adapted for different lines of buttons. The cutting practice in any plant will, however, be adapted to varying market demands, rather than to any theoretically ideal scheme for the most effective use of the shell.

Species and Sizes of Shell That May be Adapted for Different Lines of Buttons.

Common name.	Species.	Lines of buttons.			Remarks.
		Small shells.	Medium shells.	Large shells.	
		Lines.	*Lines.*	*Lines.*	
Mucket	Lampsilis ligamentina	14–18	14–22	14–30	
Yellow sand-shell	Lampsilis anodontoides	14–16	14–20	14–24	This species usually exported for novelty work.
Slough sand-shell	Lampsilis fallaciosa	14–20	14–20	14–20	
Fat mucket	Lampsilis luteola	14–20	14–20	14–20	Good shell only in certain regions.
Washboard	Quadrula heros	14–20	14–24	14–40	Often much waste on account of spotting.
Three-ridge	Quadrula undulata	14–20	14–24	14–30	
Niggerhead	Quadrula ebenus	14–16	14–20	14–24	These species yield a proportion of iridescents.
Maple-leaf	Quadrula lachrymosa	14–16	14–20	14–24	
Pimple-back	Quadrula pustulosa	14–16	14–20	14–20	

Tips are cut from all of the above-named shells. Take, for example, large washboard shells yielding 14–40 line blanks. The shells are first taken to the 40-line cutter, who cuts out all the 40-line blanks that are of the proper thickness with a true face (Pl. XLIV). They are then taken to another cutter, who cuts out all the 24-line blanks that are available. Finally, they are passed to the tipper, who cuts the remainder of the available material into 14 and 16 line tips. These tip blanks when run through the blank classifier may turn out a good per cent of blanks that are classed as butts, meaning by this that they are thick enough to make into any style of button; the tips are usually so thin that they must be finished with a machined face that requires the least material to be taken from it.

At first glance the process of cutting might appear a very simple one, yet it is properly an operation requiring much skill on the part of the laborer and the wisest type of management. A fuller discussion of the significance of the cutting room in the proper utilization of shells is given on pages 82–87.

FINISHING PROCESSES.

Preparing the Blanks.—Before going to the finishing machines the blanks are usually passed through four intermediate processes.

The blank classifier is essentially similar to the shell classifier on a smaller scale and need not be described in detail (Pl. XXXVIII, fig. 1); by falling between rollers the blanks are separated into different lots according to thicknesses (Pl. XXXVII, fig. 2).

They are then placed in tumblers, consisting of heavy and slowly revolving barrels of iron or wood (Pl. XXXV, fig. 2). In these the blanks are churned with water and pumice stone to clean them and remove the rough edges, making them easier to handle and more workable. Lye is sometimes used in connection with the pumice stone. As a cheaper abrasive of more rapid action, fine sand may be used with the pumice stone.

The blanks are now ready for the grinder, a machine fitted with an emery wheel which grinds away the horny backs and reduces the blanks to a uniform thickness (Pl. XXXV, fig. 5). These machines are operated by girls, who place the blanks face down upon moving belts 3 or 4 inches wide, while the belts convey the blanks underneath the emery wheels. These machines, as well as all others that require it, are generally connected by suction tubes with blowers for removing the dust that would otherwise

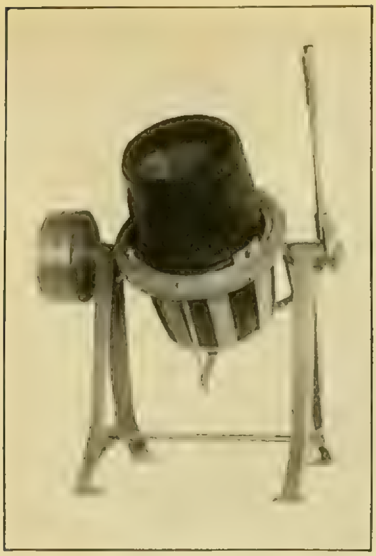


FIG. 1.—The churn used in polishing buttons. (See p. 77.)

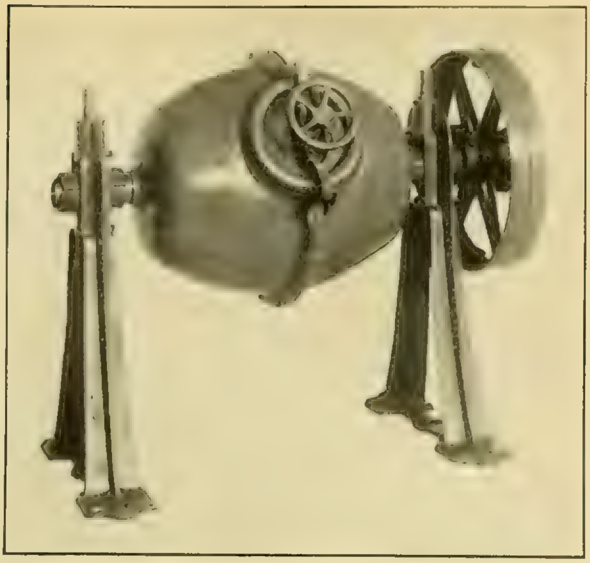


FIG. 2.—The tumbler employed for buffing blanks or buttons. (See p. 74.)

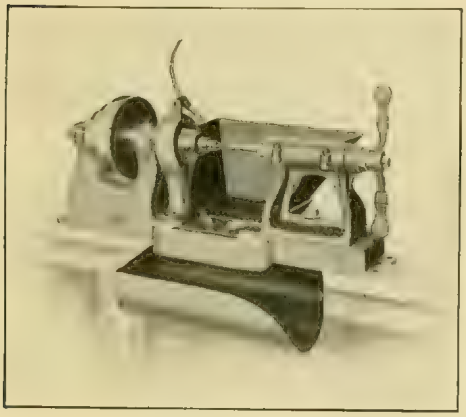


FIG. 3.—A cutting machine of simple type. (See p. 71.)

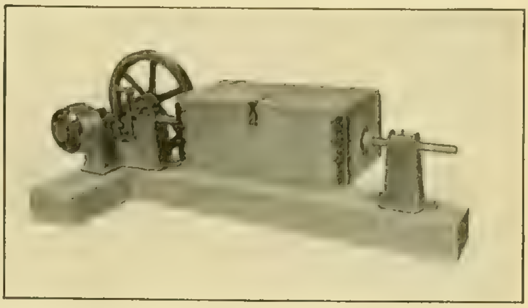


FIG. 4.—The shaker in which the buttons receive the final polish. (See p. 77.)

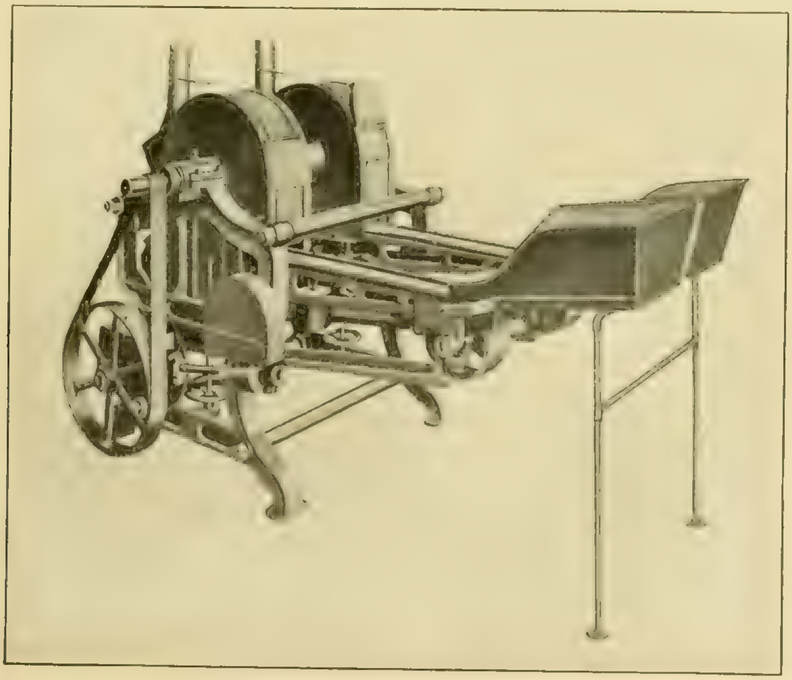


FIG. 5.—The belt grinder employed to remove the backs from blanks and bring them to desired thickness. (See p. 74.)

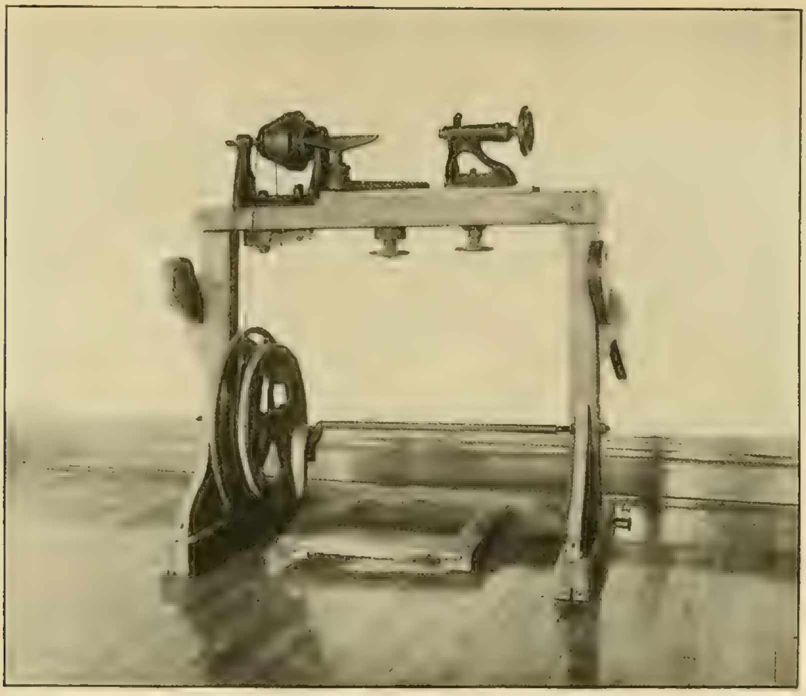


FIG. 1.—The original foot-power lathe employed by Mr. Boepple in the inauguration of the fresh-water pearl-button industry. (See p. 65.)

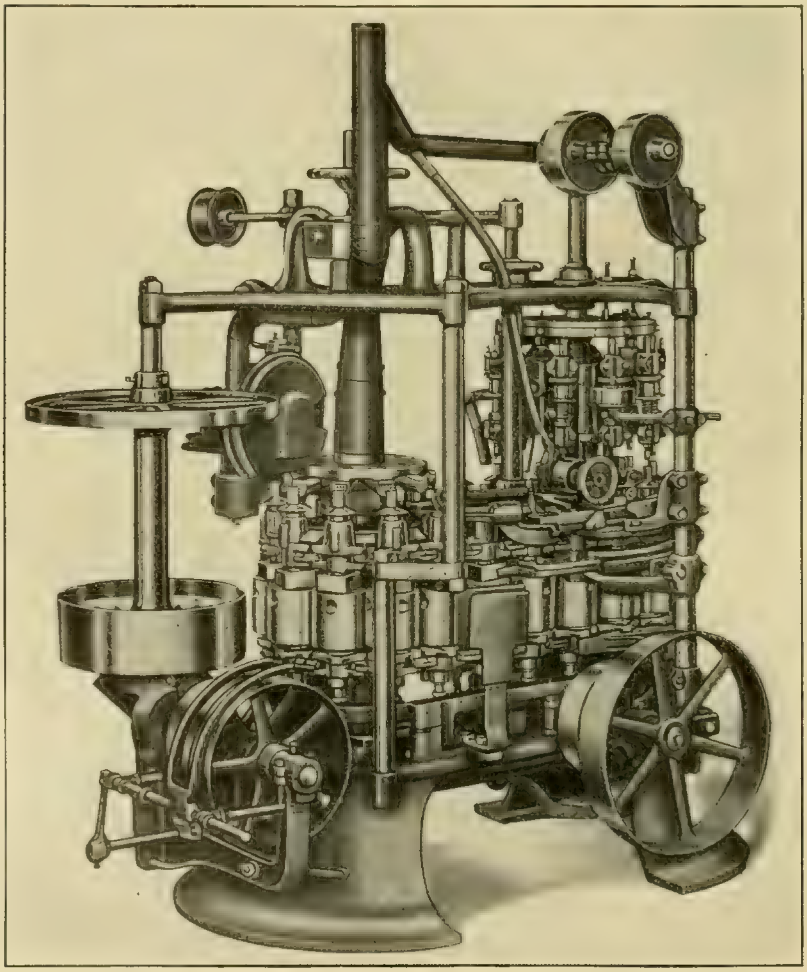


FIG. 2.—A modern automatic machine for shaping and drilling buttons. (See p. 75.)

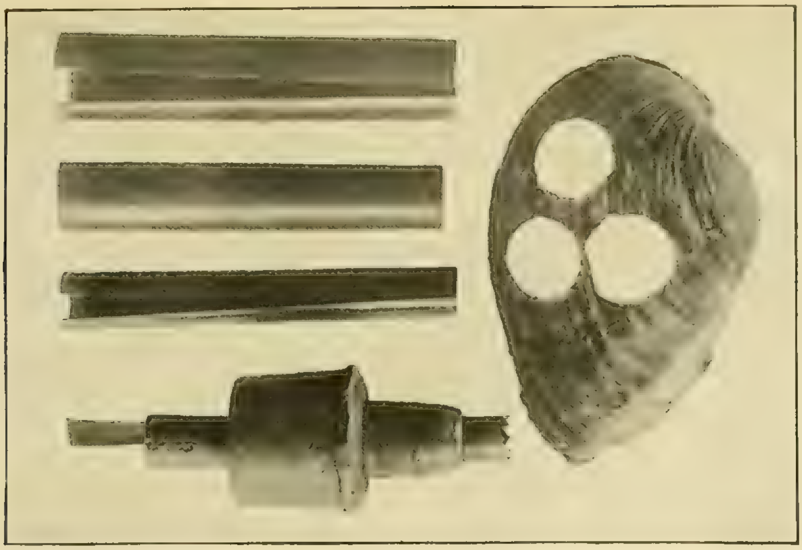


FIG. 1.—Tubular saws of different sizes, saw and spun fitted into the chuck, and shell from which blanks have been cut. (See p. 71.)

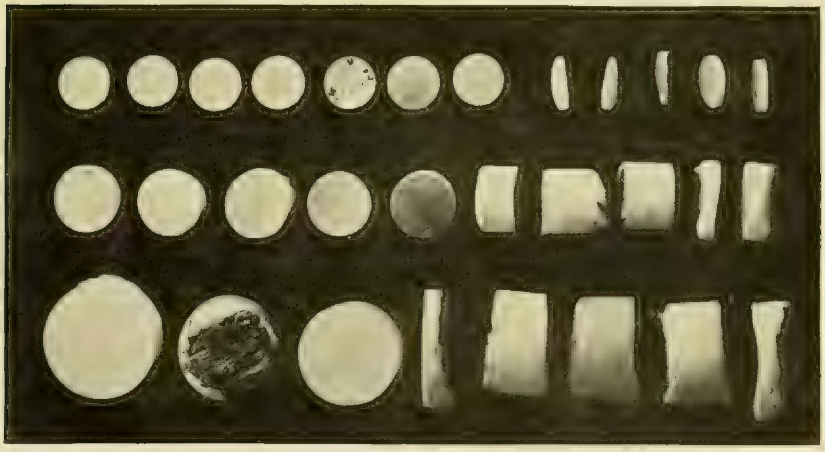


FIG. 2.—Blanks of various sizes and thicknesses as cut from the shell and before submission to the "backing" process. (See p. 74.)

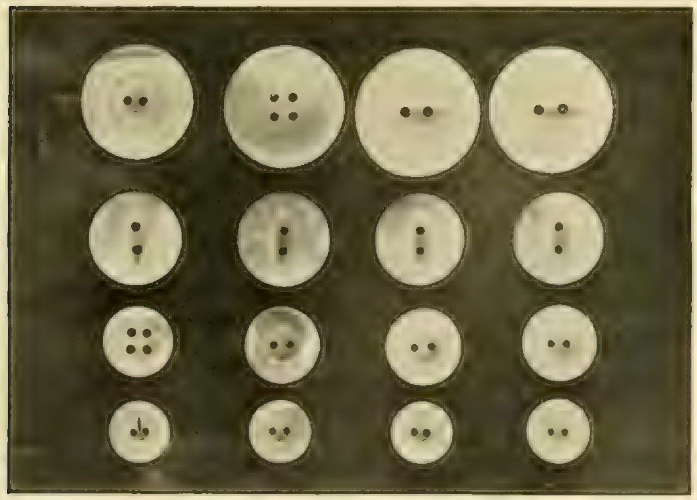


FIG. 3.—Finished buttons of several sizes and patterns. (See p. 76.)

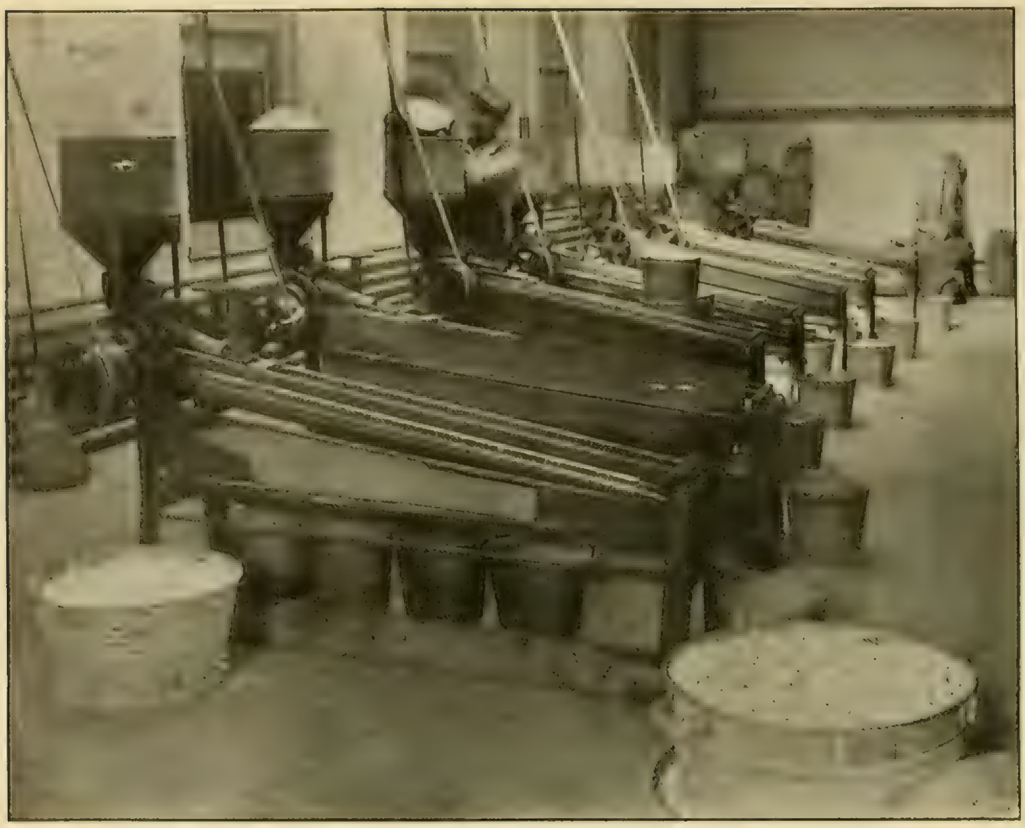


FIG. 1.—Blank classifiers for separation of blanks according to thickness. (See p. 74.)

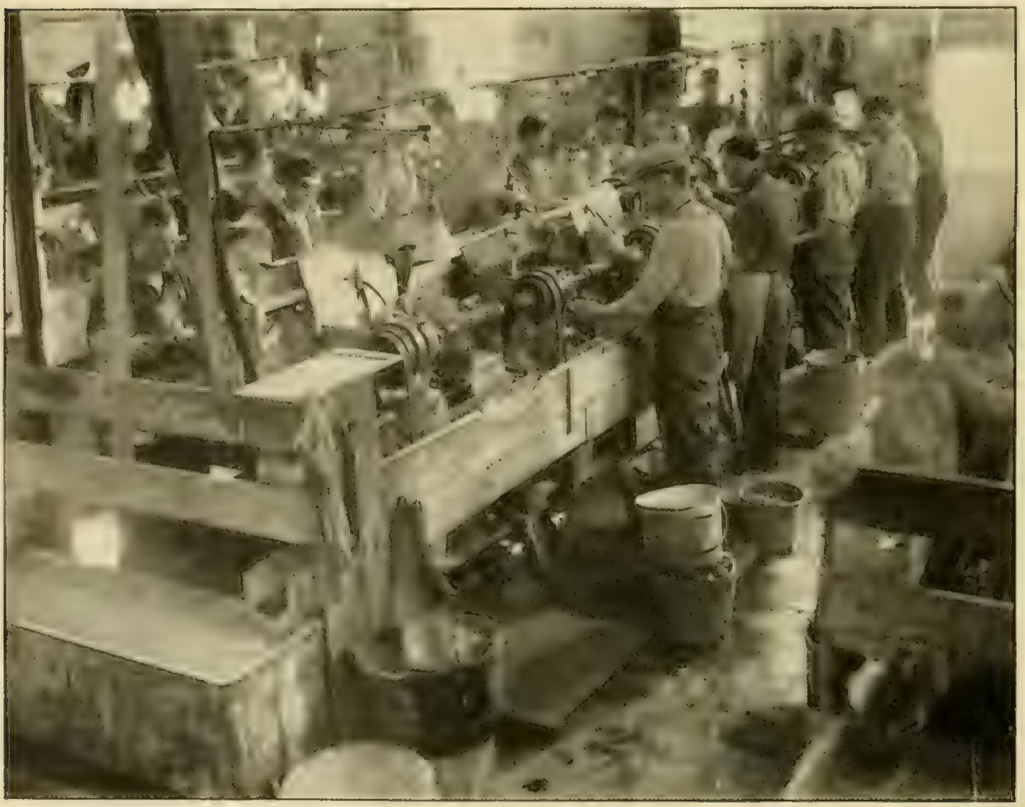


FIG. 2.—The cutting room, where blanks are cut from the raw shells. (See p. 72.)

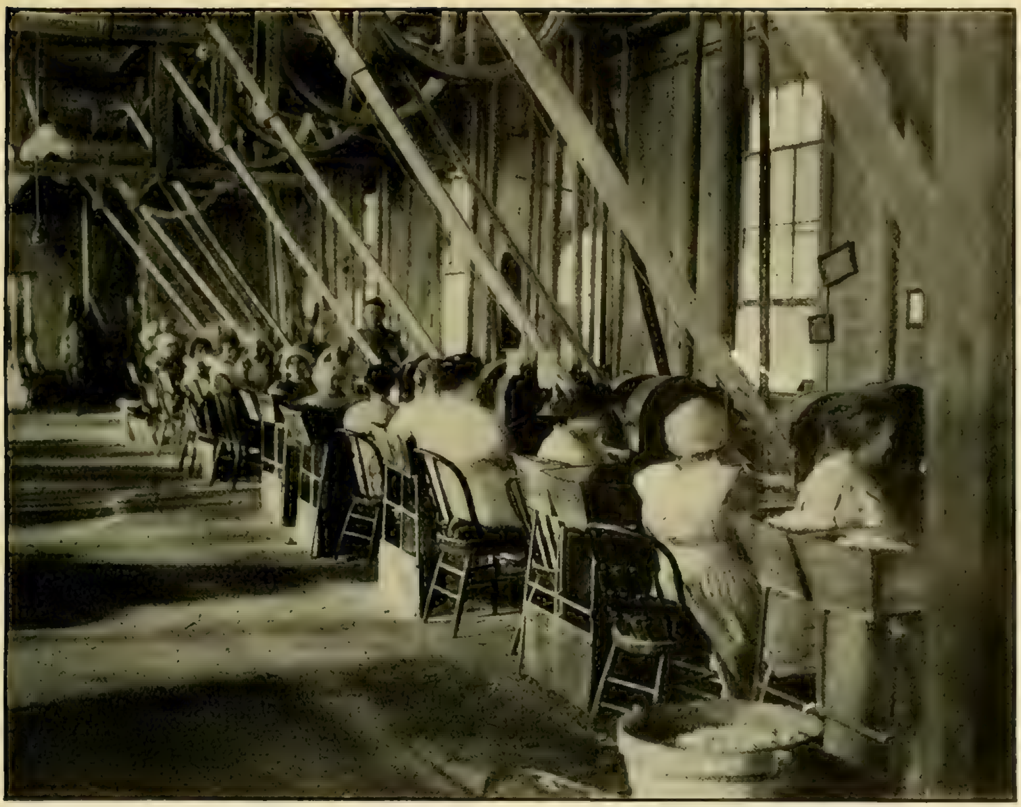


FIG. 1.—The belt grinders, where blanks are brought to uniform thickness. (See p. 75.)

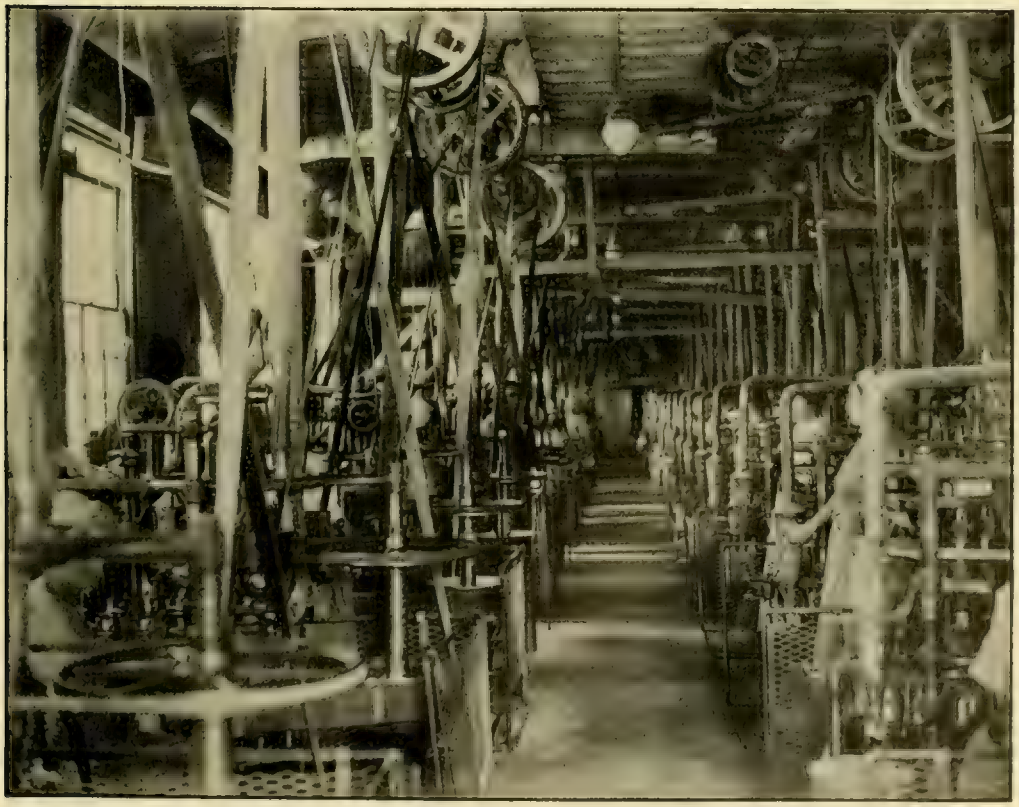


FIG. 2.—The "finishing" room, where the blanks are converted into buttons by automatic facing and drilling machines. (See p. 75.)

be obnoxious and injurious to employees (Pl. XXXIX, fig. 1). Grinders are paid from 15 to 25 cents per 100 gross, according to size and thickness of blanks, earning from $9 to $15 per week.

Finally the blanks are again soaked in water to be softened for the finishing machine. In some cases, if too much mixed in quality or size, the blanks may be sorted by hand.

MAKING THE BUTTONS.—Having been classified, tumbled, backed, and soaked, the blanks are now ready for the essential processes of button making, which are accomplished by an automatic machine of comparatively recent invention and of very ingenious design. The illustration (Pl. XXXVI, fig. 2) will aid in an understanding of the brief description of the working of the machine which can be here given. (See also Pl. XXXIX, fig. 2.) The blanks are fed by hand into depressions in the tops of vertical chucks, which are arranged in series constituting an endless chain. As the chucks in endless chain pass around the circumference of the machine each blank is automatically operated upon by various tools, and each tool is automatically sharpened and prepared for the succeeding blank. The processes accomplished in the machine consist in rounding the edges and carving out the center in the desired pattern to make the face of the button and in drilling two or four holes according to pattern. After the first hole the drill rises, the button makes a turn through a fourth or a half of one revolution (according to whether it is to be a four-hole or two-hole button), when the drill again descends to make a new hole. After the last hole is drilled the chuck opens automatically to release the button, which is sucked into a tube connected with the blower system to be dropped into a bucket through a counting tube.

Some twenty-odd distinct operations are combined in the double automatic machine, and it is interesting to record them. Let it be noted that the button travels in an oblong orbit, while the carving tools and the drills, respectively, travel in smaller circular orbits at opposite ends of the button orbit.

1. The traveling chuck, which is open after releasing a finished button, closes on the new blank placed in the top depression.

2. The chuck with the blank begins to revolve rapidly on its axis while continuing to travel to the right.

3. The face of the revolving and traveling button is applied to a carving tool of proper form to make the desired face. The tool itself is stationary on its axis, but travels in orbit with the buttons.

4. The facing completed, the tool rises.

5. The rotation of the blank is stopped.

6. The tool, continuing on its orbit, is sharpened on an emery wheel.

7. Before meeting another blank the tool is lowered by a small fraction of an inch to compensate for the shortening due to the grinding on the emery wheel.

8. The chuck, with its blank, leaves the orbit of the carving tool at a tangent to pass over to the orbit of the drilling tools.

9. When the blank is in just the right position, one of the drills descends to make the first hole in the blank. In this operation the drill revolves, while the blank is stationary on its axis, but both travel together.

10. The drill rises.

11. The chuck, with blank, turns through one-fourth of a revolution.

12. The drill descends for the second hole.
13. The drill rises.
14. The blank turns another fourth of a revolution.
15. Third hole is drilled.
16. Drill rises.
17. Blank turns.
18. Fourth hole is drilled.
19. Drill rises.
20. Drill continues in its shorter circular orbit, to return into proper position for a later blank.
21. Button chuck rises a little and releases the button.
22. As the chuck passes beneath a suction tube the button is drawn up against a small, fine screen in the tube.
23. The button drops of its own weight upon a small trap.
24. When a number of buttons corresponding to a given weight have accumulated on the trap it releases and drops the buttons into a bucket.
25. The tripping of the door or trap registers the number of buttons finished.

Another feature of the machine is the equipment of little screened suction tubes, some traveling, and some stationary, which draw away the dust whenever it is generated by carving or drilling. The amount which the carving tool may be lowered to compensate for grinding can be fixed by a large ratchet disk over the machine, which permits of adjustment to the one-thousandth of an inch.

When the fisheye pattern (cf. Pl. XXXVII, fig. 3, buttons in second row from top) is desired, a thin, revolving emery wheel, or a steel fish eye cutter, is placed so that as the button passes from the carving orbit to the drilling (without central depression) the tool swings down and at one stroke cuts out the fisheye. There may also be an attachment for causing the blank to turn upside down, so that the back may be hollowed out instead of being left flat or rounded, as is ordinarily the case.

This machine as described is the double automatic button machine. Somewhat older types are the single automatics, where separate machines embody the processes of facing and drilling. These are still in use in some factories. A very recent addition to the button machine consists in an automatic grinding and feeding attachment, whereby the blanks are first backed and then dropped into the chucks from an endless belt. As the machine is generally used, the blanks are placed individually in the chucks by the attendant, usually a woman, who becomes very expert.

It will be recalled that the blanks were tumbled before being backed. In consequence, as they come to the automatic machine the back edges are slightly sharper than the edges corresponding to the inside surface of the shell. It is possible, therefore, for a deft operator to distinguish at the touch the outside surface from the inside and so to place the blanks in the chucks that the one side or the other (as desired) will be finished. There seems to be some difference of practice, nearly all manufacturers believing that the inside gives the best finish, while some find a better product by finishing the outside. Experiments made at the Fairport station do not indicate a marked difference. Possibly a better or more uniform gloss is obtained on the outside, while a more pearly "water" results from finishing the surface corresponding to the interior of the shell. However, an obvious advantage in carving the inner surface

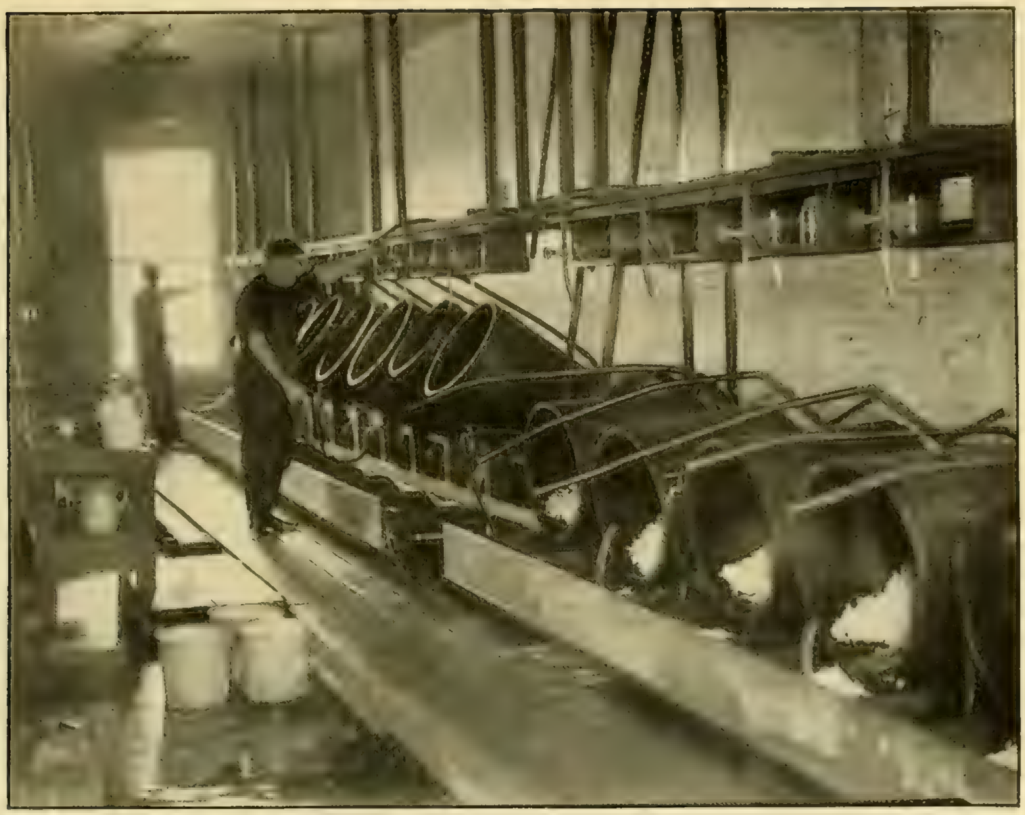


FIG. 1.—The churns, with buttons receiving polish by the use of acid and steam. Note the funnels from which acid solution drips into the churns. (See p. 77.)

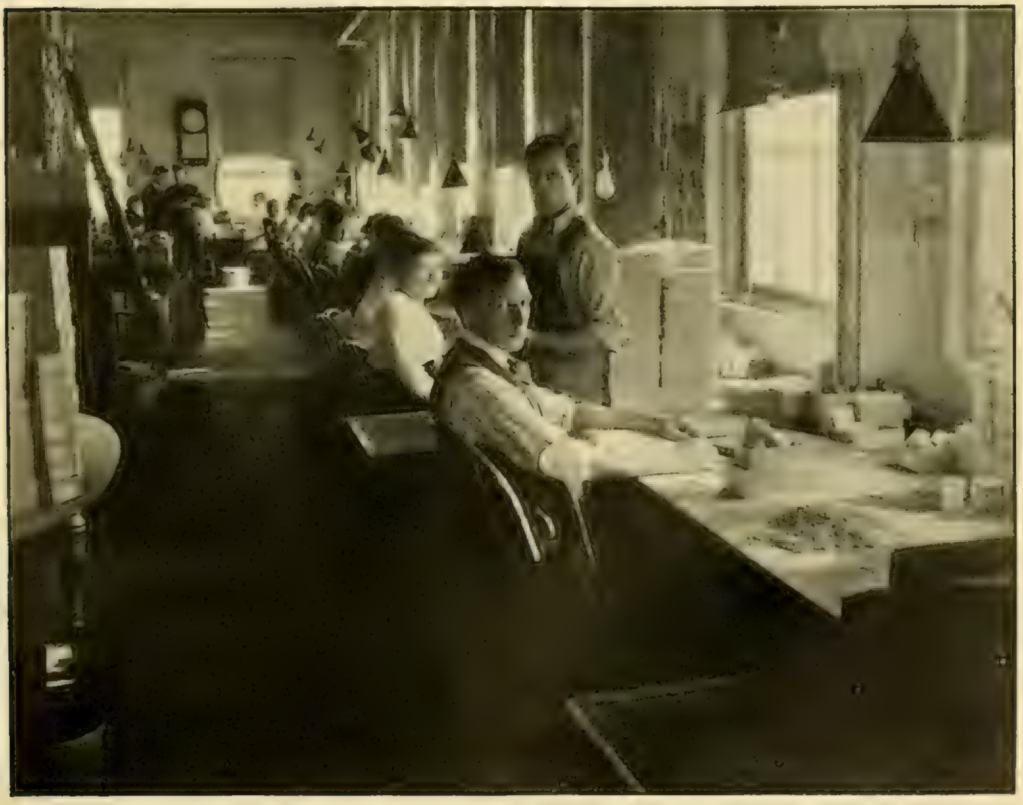


FIG. 2.—The sorting room, in which skillful operators classify buttons into 12 grades. (See p. 77.)

arises from the fact that the outside, after having been backed, is flat and true, while the inner face may have a natural unevenness. The blank on its back or flat side thus rests more securely in the chucks of the finishing machine and, when finished, both sides are in such true form as desired.

Assuming each chuck to be properly filled in turn, a machine might finish from 33 to 72 buttons per minute, according to the speed given it. Ordinarily the capacity varies from 100 to 190 gross per day. In the days of handwork the output of a single operator in shaping was about 20 gross per day, and the buttons had then to be passed to the driller, who could turn out about 50 gross per day. The cost of a double automatic machine in 1914 was about $1,300, with about $300 additional for the feeding attachment, but a machine would probably cost $2,500 in 1919. The operators are usually women, who were paid, in 1914, 1 to 2 cents per gross and earned $7 to $11 per week. In 1919 the rate of pay and earnings are 33⅓ per cent higher.

The automatic machine has revolutionized the industry of button manufacture from fresh-water shells. It makes possible not only a far greater yield, but a better uniformity of product than was ever possible with handwork. Something is yet to be desired in the way of lessening the amount of breakage of blanks in process of manufacture, but the machine is being continually improved and perfected.

POLISHING.—From the machine the buttons are taken to the churns, where they are tumbled, or churned, with water and pumice to clean them, take off the rough edges, and make them ready for receiving the final polish (Pl. XXXV, fig. 1 and Pl. XL, fig. 1).

The polishing is also a tumbling process, in which, however, sulphuric or other acid is used in conjunction with steam. After the buttons are dried in shakers with sawdust (Pl. XXXV, fig. 4), they are placed with dry sawdust and washing powder in a combined tumbler and shaker. This process removes any trace of limy deposit and gives the final luster. Finally the buttons are conveyed in buckets or boxes to the sorting room.

SORTING.—A very important feature of a button factory is the sorting room, for the qualities and grades can not be sold if mixed indiscriminately. The classifying according to sizes and thicknesses has already been accomplished in the blank stage, but the grading according to freedom from defects of manufacture or from natural shell stains and with respect to color, luster, and iridescence must be accomplished by the hands and eyes of skilful sorters. Girls are always employed for this work on account of their superior deftness, or quickness of selection, and the most expert sorters can separate the buttons into 12 grades with extreme rapidity. They are provided with a well-lighted room and work seated in rows at long tables before windows (Pl. XL, fig. 2). The buttons are handled individually and thrown into series of boxes or drawers arranged about the operator; from 85 to 200 gross of buttons may be sorted in a day, so that sorters might earn, in 1914, from $5.25 to $12 per week, on the basis of pay at one cent a gross. In 1919, sorters are apparently earning from $10 to $19 per week on a sliding scale wage of 0.6 to 1.15 cents per short gross according to the number of grades (from 2 to 12) sorted.

The number of grades varies with the several establishments, but it would not be practicable to enumerate them. Some factories make a specialty of iridescents or shiny-backs, as they were originally called. The iridescents are made from the hinder portion of the niggerhead, pimple-back, and related shells. If a niggerhead shell is polished on the outside, there is seen to be an almost exact dividing line between the smaller brilliantly iridescent portion and the larger merely lustrous portion. Muckets and related shells produce no iridescent buttons. Some may be obtained from the bluepoint, three-ridge, and washboard, but these are often not otherwise up to grade in quality. Buttons from these shells often require bleaching, and it has been observed that the process of bleaching increases the degree of iridescence.

Although iridescents, when carefully selected, command a good premium, they are comparatively too few to make it generally worth while to work particularly for them. Care must be taken that the entire button is cut from the iridescent portion without overlapping of the forward portion of the shell. As a rule, no special effort is made to cut them, but as a number are cut incidentally, a premium may be paid to the sorters to separate them from the others. In consequence a limited number of clear iridescents are obtained which can be sold at a good price. When ordinary buttons of good grade were bringing 38 to 40 cents per gross, iridescents would bring 75 cents. Indeed, if there were any regularity of supply the price could undoubtedly be raised much higher and still the demand be good.

BLEACHING AND DYEING.—References have previously been made to the prevalence of stained, spotted, or otherwise discolored shells. Such shells or portions of shells constitute a considerable proportion of the undesirable waste. Manufacturers have long striven to find proper processes of removing the discoloration without detriment to the quality of the product. Old methods of bleaching embraced the use of alkalies which injured the shell and caused the buttons to disintegrate or to break in the laundries. Hence bleaching came into disfavor in the trade, and some purchasers decline to purchase buttons believed to have been bleached. Bleaching as now generally practiced, however, is not injurious. Factories employing this process have each their own peculiar formulas or methods, but until very recently the essentials of the process were probably the same in most plants—peroxide, chloride of lime, and heat, with variations in the degree of heat and the period of action. Other chemicals are now employed in secret processes which seem to be very effective.

Without bleaching, discolored buttons may be used to advantage for the production of smoked-pearl buttons, which are blackened by staining with sulphur and silver nitrate. Various dyes are also used in the production of fancy buttons of bright colors, as red, green, or blue, to suit the capricious demands of fashion. Some are now being so treated chemically as to produce an excellent imitation of the buttons made from the Trocha shells of Japan, but with better finish. Many shells in nature have beautiful colorings of purple, salmon, or pink, but the shades are not adapted to market demands, and it is claimed that the colors are liable to fade unevenly. Consequently, beautiful as some shells appear in natural condition, they must be classed as waste unless some effective process of bleaching or staining be applied.

CARDING, PACKING, AND SALE.—Certain factories work for the bulk trade—that is, for the supply of garment manufacturers who do not require the goods carded; others for the carded trade exclusively, while some are prepared to supply both.

If the bulk trade is supplied, it remains after sorting only to pack and ship; otherwise, the buttons must be attached to suitable cards. Sometimes the sewing is done in the factory; in other cases, more so in the past than at present, buttons are given out to women at home who wish to earn pin money at spare moments.

Within the last two years a machine has been introduced for neatly attaching the buttons to the cards with small wires. It has the advantage of not only saving time, but of attaching the buttons individually, so that a single button may be removed without loosening the others from the card. This is a convenience to the consumer as well as to the manufacturer; for if, after carding, it is noted that a defective or an off-grade button appears on a card, it can easily be removed and another put in its place with a special machine. These wire-stitching machines are usually operated by girls, with one or two men to keep the machines in order. A single machine may turn out 150 gross per day, more or less. The record in May, 1914, was 240 gross stitched to the cards in 9.5 hours. The operators were then paid from seven-tenths of a cent to 1 cent per gross (about 1.2 cents in 1919), and might earn $6 to $10 per week ($8 to $11 in 1919). The machines were not sold, but were operated on a basis of hire or lease.

After carding, the buttons are ready to be boxed and sold. Individual manufacturing establishments have specialties in the way of attractive cards and boxes or display outfits. Naturally the departments of advertising and selling have much to do with the success of the factory and constitute a considerable element of overhead expense. The wholesale price of buttons varies between wide extremes. Buttons of 45 lines and excellent quality may be sold as high as $2.25 per gross; or an overproduction and accumulation of low-grade lines have led to sales at as low a figure as 1 cent per gross. Owing to the large number of low-grade buttons sold in bulk, the average price per gross, as computed from a statistical survey of the industry conducted by the Bureau for the year 1912, was about 23.5 cents per gross. As this price probably covered freight, insurance, and discounts, the net factory price would have been correspondingly lower.

The elements of cost in the manufacture of buttons must vary very widely according to the grade of the shell, the line of the button, the quality of labor, the size and output of the plant, and the systems of management. By courtesy of a manufacturer we may illustrate by the following citations of costs in particular lots of material which were carefully followed through the various processes of manufacture. The items in each case are as nearly correct as could then be made (1915), but the same tables would not apply exactly to other batches of the same lines. The data serve a useful purpose as illustrating relative costs of the several processes, although the prices of shells and the cost of labor have increased materially (approximately 75 per cent) since 1915.

RELATIVE COSTS IN THE SEVERAL PROCESSES OF BUTTON MAKING, AS OF THE YEAR 1915.

Items of cost.	Example of 16-line buttons.	Example of 20-line buttons.	Example of 28-line buttons, better grade.
Shell	$0.0335	$0.0524	$0.1667
Cutting	.0523	.0689	.1075
Overhead expense in cutting	.0196	.0194	.0393
Grinding	.0015	.0018	.0057
Overhead expense in grinding	.0125	.0125	.0125
Machining	.01	.01	.015
Overhead expense in machining	.015	.015	.015
Sorting	.01	.01	.01
Overhead expense in sorting	.014	.014	.014
Total (allowance for losses in process of manufacture not included)	.1684	.2040	.3857
Ratio of shell cost to total ... per cent	20	26	43

Many of the cheaper buttons are manufactured, really, in the way of by-products; that is, the shells must be bought for the making of good buttons, and the cost of the shell is chargeable to these profitable lines; it is better then to cut the remainder of the shell into very cheap grades than to throw it away. There are times, however, after the demand for the poorer grades has been oversupplied, that it becomes actually necessary to discard waste shell, unless one is to manufacture at a serious loss.

UTILIZATION OF WASTE PRODUCTS.

In 1912, according to a statistical survey conducted by the Bureau, 55,671 tons of shells were used for the manufacture of buttons. Assuming that only 90 per cent of this material became a waste product in course of manufacture, we find 50,000 tons of waste material. This waste consisted principally of shells discarded after cutting out the blanks, but a considerable quantity was in the form of finely pulverized shells or dust generated in the processes of cutting, backing (or grinding), facing (or carving), and drilling. This dust is not permitted to escape into the air, as otherwise the atmosphere of a factory would be unendurable. It is removed and concentrated by streams of water played on the shell while cutting and by a system of blowers and suction tubes connected with the several elements of finishing machinery. The dust is, therefore, made available for use.

The uses of the waste material would be various were it not for the fact that other cheaper materials are available for many of the purposes for which it is adapted. For instance, the waste shell might be burnt for lime or used for the improvement of soils or for many common purposes.

The principal use of the waste shell is for the production of poultry grit, for which purpose it is prepared by passing it through crushing machines, which divide it into the desired fineness; defective or broken blanks and unmarketable buttons also pass into the crusher (Pl. XLI). The waste shells are sometimes used also as road-building material. The shells are very hard and do not pulverize so readily as oyster shell. In this respect there are obvious disadvantages as well as advantages.

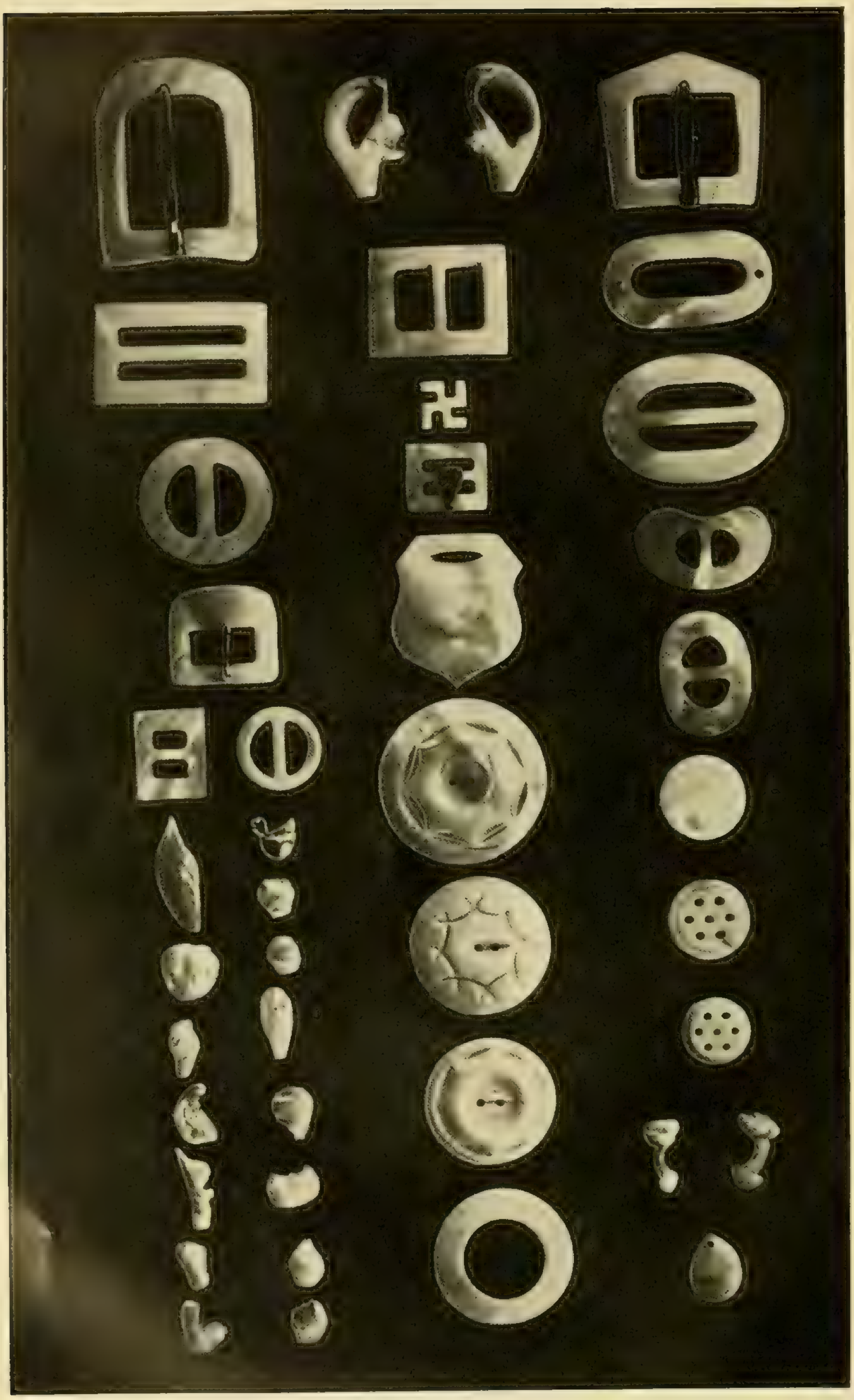
The dust is useful in stock food, and in condition powders for hogs and poultry; it serves also appropriate purposes as an element in the manufacutre of artificial marble, tile floorings, etc. It is said to form a constituent of some jewelry polishes, soaps, and cleansing powders. The present market for dust is, however, nearly negligible.

In 1912, 22,530 tons of crushed shell were sold, yielding $114,722, besides about 10,500 tons of shell not crushed which were sold (probably largely to crushers) for $7,600. The sale of dust amounted to only 1,220 tons, bringing $3,470. The shell commanded about $5.50 per ton, and the dust about $4 per ton. In 1919 shell and dust yield, respectively, about $12.50 and $1 per ton. Both the shell and the dust possess certain exceptional qualities, and undoubtedly in time a better place in industrial uses will be found for them.

USE OF SHELLS FOR NOVELTIES.

The production of novelties from fresh-water mussel shells takes a wide variety of forms (Pl. XLII). In 1912 there were six novelty works with an output valued at $61,800. From small whole shells or from portions of shells there were made such articles as watch charms, hatpins, stick pins, buckles, chains, cuff buttons, fancy buttons of all sizes and

Crushing plant where waste shell and defective blanks are converted into chicken feed and other useful products. (See p. 80.)



Novelties made from portions of fresh-water mussel shell. (See p. 80.)

many patterns, perforated tops for salt shakers, inlaid work, etc. Most of the novelty works are located in Muscatine, Iowa.

The yellow sand-shell, being a rather long, straight-lined shell of peculiar pearliness, though not a clear white, is particularly adapted for novelty work, and thus commands such a high price that, under normal conditions, no manufacturer can afford to cut buttons from it. Shells of this species were often sorted out by the shellers on the river bank to be sold at a price two or three times the value of button shells, or from $40 to $60 per ton. Such shells as were not sorted out, but sold along with less valuable material, were subsequently again sorted out by the manufacturer for resale. Practically all of these shells were exported to Germany, where they were highly valued. Such shells for export sold as high as $90 per ton f. o. b. New York.

The Daily Consular and Trade Report of January 6, 1914, stated that there was a steady demand in Hamburg for the following grades of American shells, prevailing prices c. i. f. Hamburg per 220 pounds being quoted as follows:

		Equivalent price per ton of 2,240 pounds.
Niggerheads	$5.95	$60.58
Muckets	4.76–$13.09	48.47–$133.37
Yellow sand-shells	11.90– 16.66	121.16– 169.63

Prices of marine shells at the same time were reported as ranging from $7.14 to $107.10 per 220 pounds (equivalent price per ton, $72.43 to $1,090.47).

PROCESSES FOR POLISHING SHELLS.—Polished shells of the iridescent varieties make attractive souvenirs or table ornaments. The polishing may be accomplished by one of the following methods, as described by J. B. Southall, shell expert of the Fisheries Biological Station at Fairport:

Buffing process.—The outer surface of the shell is ground off by an emery wheel or grindstone, the former being preferable, as it grinds much faster. If the surface of the shell is grooved, a file is generally used to remove the portions of the surface not touched by the grinding wheel. After the outer surface has been removed the shell is polished by holding it against a felt polishing wheel revolving at the rate of 2,000 to 3,000 revolutions per minute, fine polishing paste being applied to the surface of the wheel as needed. When all the emery scratches have been removed, the shell receives its final polish by holding it against a canton-flannel buffing wheel revolving at the same rate as the polishing wheel. If many shells are to be polished a double emery-wheel stand can be used to advantage by having the polishing wheel on one end of the spindle and the buffing wheel at the other end.

Chemical process.—If the entire shell is to be polished—that is, the inner and outer faces—prepare the shell the same as for buffing. After the surface has been ground off the shells are placed in a cylindrical tumbler, using enough water to cover and a reasonable amount of fine pumice powder. It usually requires 8 to 10 hours of tumbling to remove the emery scratches and smooth the outer face of the shells. After the shells are smooth enough they are taken from the tumbler and placed in the polishing machine.

Polishing machines can be purchased on the market, but a very good homemade machine can be constructed at a small outlay. Mount a short piece of 1-inch shaft in a frame so that the shaft inclines at an angle of 45°, and at the upper end fasten an earthenware jar of suitable capacity. The ordinary speed for the polisher is 40 to 60 revolutions per minute. The jar being tipped at an angle of 45°, the shells are tumbled over one another instead of resting on the bottom of the jar and moving with it, thereby allowing the acid to remain on the shells and cause pitting. A most convenient acid dropper is made by cutting a very narrow groove in the side of a cork and inserting it firmly in the tube of a glass funnel. With a little practice the number of drops to the minute can be regulated by the size of the groove in the cork. The next operation is to place the shells in the polishing machine and pour in a measured quantity of water just sufficient to cover them completely. A quantity of sulphuric acid equivalent to 20 minims for each 8 ounces of water in the jar is then placed in the dropper, which should be suspended over the polisher and so adjusted that the acid will fall into the jar at the rate of 10 to 15 drops per minute. A very good plan is to take some of the water out of the jar and add it to the acid in the glass funnel, thus diluting the acid, and diminishing the danger of pitting the shells by allowing the pure acid to drop on them. It generally takes from 45 to 60 minutes for the polishing, if the acid has been gauged correctly. Just before the shells are polished the water becomes milky. Do not allow the shells to stay in the water long after the milkiness appears, as the shells soon become coated with a white substance which is very hard to remove. After the desired polish is obtained dump the shells out and wash thoroughly with clean, cold water; then wash the polisher, place the shells back into it, covering them again with clean water, and revolve as before, applying steam to the water with a hose until it boils. Just as the water comes to a boil pour in an amount of commercial muriatic acid equal to that of sulphuric acid used in the first operation and allow the shells to tumble a couple of minutes after the acid has been poured in. Remove the shells and wash as before. After washing the shells allow them to dry for 48 hours; then place them in a box tumbler and allow them to tumble in good, clean sawdust for a couple of hours. In this way the shells are buffed and receive the finishing polish.

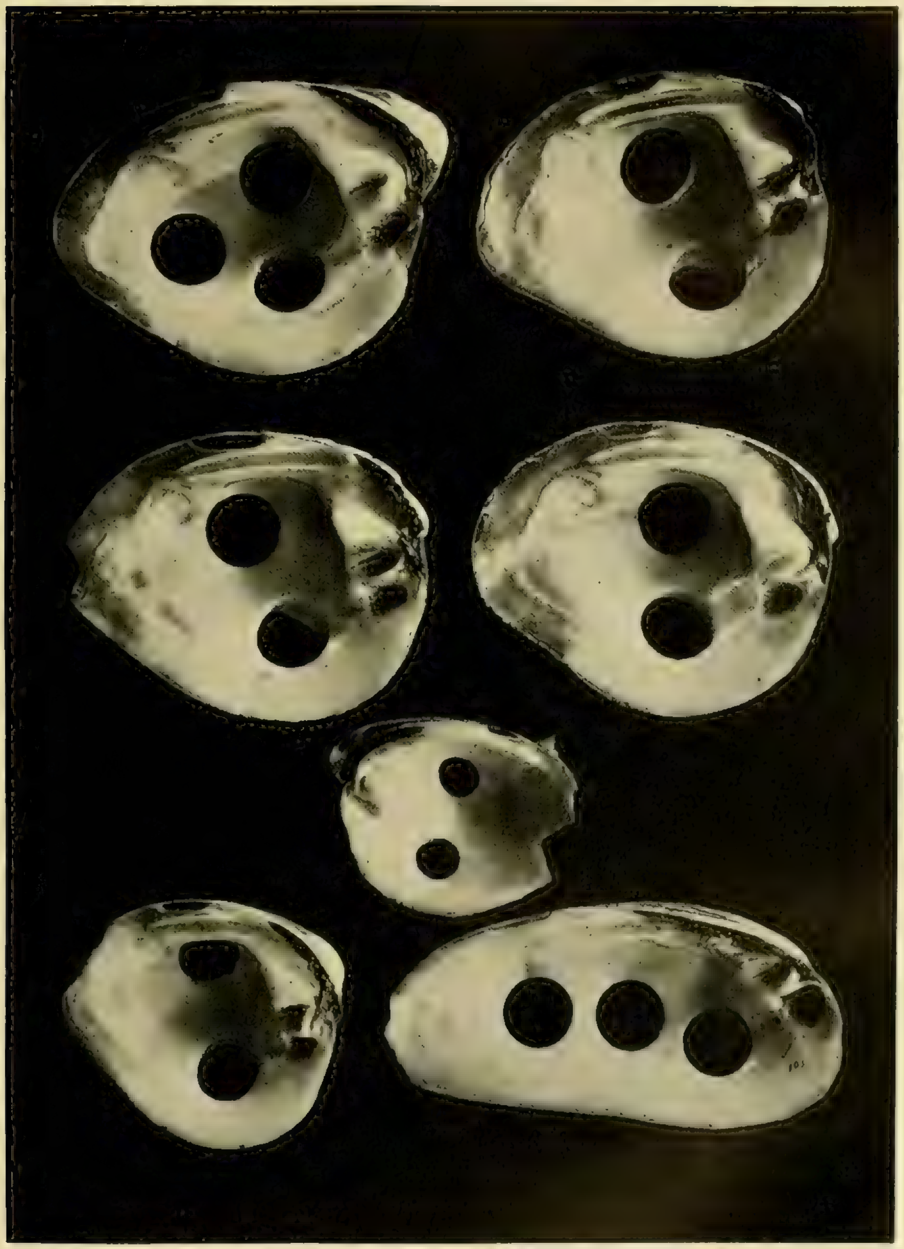
ECONOMY AND WASTE.

THE PROBLEM OF CUTTING.

In the early period of the button business, owing to the entire want of skill of the cutters and the apparent abundance of the shells, a most wasteful use of shell prevailed. Two or three blanks were cut from shells which should have yielded two or three times as many (Pl. XLIII). Factories could not now exist with such sacrifice of raw materials as then occurred. As a matter of fact, when new factories were continually forming in the early days, each eager to obtain cutters from other factories, it was impossible to maintain system in the cutting department, and a confessedly unfortunate condition prevailed.

With a condition of greater stringency bringing a necessity for better economy, the difficulties in the administration of the cutting department were augmented to the point of becoming a serious menace. Naturally, the need for betterment was first appreciated by the manufacturer; but the ways and means of bringing system and economy out of a condition of disorder and waste were at first baffling.

The process of cutting is at first glance a very simple one, and until rather recently the work of cutting was not generally understood to be skilled labor, nor was it really practiced as such. Nevertheless, in no part of the factory is the opportunity greater for



Illustrating wasteful cutting practiced in earliest stages of fresh-water pearl-button manufacturing industry. Compare ensuing plates. (See p. 82.)

the exercise of care and good judgment on the part of the laborer or for intelligent and sympathetic cooperation between management and labor.

The problem of the cutting room is, indeed, a complex one owing to the difficulty of maintaining an exactly definable standard or of arriving at a system of count and payment that is at the same time neither open to criticism in some features nor conducive to waste. The desideratum of course, is a working plan, that neither denies to the cutter any portion of his reward, nor, on the other hand, relieves him of due responsibility for the cutting of shells in the best interest of manufacture and in accordance with proper usage of material.

A great variety of shells are used, differing in size, weight, shape, and quality. No single shell is of uniform thickness throughout, but all taper, more or less, from thicker forward and center portions to thinner rim and tip; each shell, may, therefore, produce good, inferior, or worthless blank. By poor spacing an unnecessary portion of the shell may be wasted, or, from careless manipulation, an undue proportion of the blanks may be inferior or worthless. It is quite possible, too, to waste more time in the careful cutting of material than is warranted by the saving of material. Consequently it is essential to impose checks in relation to the quantity and the quality of the output and to the proportion of product to materials consumed.

DEFECTIVE BLANKS.

Since no shell is of uniform thickness in all parts, the blanks from any given shell may vary from very thick to very thin. (See Pl. XXXVII, fig. 2.) All blanks wholly or in part thinner than two lines (one-twentieth of an inch) are called tips and can only be used for very inferior buttons.[a] A blank is never too thick to be acceptable, since it can be ground down to the desired thickness; unfortunately splitting is not yet practicable with fresh-water shells. A cutter, however, may cause a rim blank to split by twisting the shell when half sawed through, thus increasing the count though the resulting blanks are undesirable. Such an unfair practice is detected when blanks are found without a back, or covering, of horny epidermis. From too much haste or too little care, the blanks, instead of being sawed clean through, may be pushed out, leaving flanges of shell and horny matter on the outside which cause much trouble in the succeeding processes. In very thick shells it is often undesirable to cut the rim, on account of the blanks having such a pronounced bevel as to work poorly or to fly out of the chucks in the process of facing and drilling and perhaps injuring the chucks or drills. It is usually better, therefore, to let this portion of the shell be wasted. Blanks cut through the eyespots (muscle scars) or through certain shell defects are sometimes undesirable. The cutter may space the blanks too closely, overlapping them, and thus producing buttons that are not round. In such a case, too, there is a danger of the saw being destroyed by the unrolling of the cylinder. (See Pl. XLV, lower left-hand corner.)

This brief account of the more conspicuous possible defects in cutting will account for the practice of counting out certain blanks; that is, of requiring that a blank, to count for payment, must be two lines or more in thickness, must have the back on, be round, clean-cut, or without ragged edges, and be not cut through such spots or portions of the shells as may be prescribed. These specifications are simple and can be complied with by any conscientious cutter. The more difficult problem is that of getting the greatest number of blanks from the shells consumed.

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[a] See footnote, p. 17.

CHOICE OF SHELLS FOR PARTICULAR LINES.

Particular sorts or sizes of shell will work up most economically for particular sizes and grades of buttons. Accordingly, much discretion may be exercised in the apportionment of shells to the most appropriate uses, having in view the market demands to be supplied. A shell may be cut entirely into one size of blanks by one cutter, or the good blanks, the button blanks, may be cut out at one machine, while the remainder is passed directly, or after a lapse of time, to another cutter for taking out the tips. In other cases the shell is first worked for a few large blanks, and subsequently more completely used for smaller sizes. In this respect a large factory has a certain advantage over the small, independent cutting shop, since the latter must cut whatever shells are on hand into the particular lines for which the market is calling, while the larger factory may select from the bins the shells suited to the temporary needs, or may return to the bins, if desired, the partly cut shells. The detached cutting plant, on the other hand, may have an advantage in the saving of freight charges on useless shells.

The assignment of the shells for particular lines depends upon the judgment of the foreman or manager alone; but a proper quantity and quality of output and the elimination of unnecessary waste are contingent upon efficient labor in the cutting room. It will be of value in this connection to give some details of shop management, especially as observed in plants marked by the economical use of shells.

SHOP MANAGEMENT.

Disregarding minor differences, the shop management is, in brief, as follows: Each button cutter is assigned a machine, but is expected to furnish certain tools. The shells are weighed out to him, and he is assigned the proper line. Cutters with the best records may be favored with the most desirable lines. At certain intervals he turns in the blanks which he has cut and receives pay at so much per "count". The count, or "gross," as it was formerly called, is not the ordinary gross of 12 dozen, but an arbitrary and long-established unit of 14 dozen.[a] Since it would be impracticable to count the entire output of each cutter, his blanks, after shaking to remove chips and dust, are turned out into a tub on the scales and the gross weight recorded. A handful may then be taken at random to weigh out a given small unit in the pan of a balance scales. The buttons from the pans are then counted individually on the table, those not acceptable (for defects previously mentioned) being discarded from the count.

The manner of count in different factories is divergent. In one, all blanks are counted as of the same value; in another, the blanks under four lines but over two lines in thickness are counted two for one. The latter plan is based on the fact that the thin blanks can be cut rapidly, and, although usable, are of relatively little value in manufacture. The former plan, that of giving the same count to tips as to good blanks, is simply "an acceptance by the manufacturer of responsibility for the shape of the shell."

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[a] Thus we find that, in the language of button manufacture, neither the unit of measure, the line, nor the unit of count for blanks, the gross, corresponds to the common usage. The line is adopted from European practice and represents one-fortieth of an inch. The gross of 168 was originally based on an allowance for breakage and other losses in the manufacture of the blank into buttons. The terms although unfortunate, are matters of custom and are understood by all immediately concerned.

Upon the basis of the sample count and the gross weight of the blanks the total count is readily computed for the purpose of payment. According to divergent methods payment may be made either at a flat rate per gross of 168 blanks, or the weight of shells used may first be charged against the sheller, and payment (at a higher unit rate, of course) is then made by deducting from the computed value of the blanks the cost of the shell at a fixed price previously agreed upon.

The difference in the two methods has to do with the fixing of responsibility for the economic use of shells. In the first case, the management alone is responsible for economy, in the second the responsibility is divided. The latter seems really fairer to the cutter than the former and puts a proper premium upon careful and efficient work.

In case of payment exclusively upon the basis of blanks returned, the interest of cutter and management are continually in conflict. The cutter is tempted to sacrifice economy of material to gross output of blanks per day, while the management must be continually endeavoring to prevent undue waste of shell. This is a condition provocative of friction and liable to result in discharges or in docking.

In the other case, the cutter understands that waste of shell diminishes his earnings. Suggestions from the foreman to show how more blanks could be taken from a given shell are, therefore, received as personal help rather than as rebukes. A single instance that came under the observation of the writer will serve to illustrate: A cutter had laid down a cut shell when the foreman pointed out how two more blanks might be cut. The cutter readily accepted the suggestion, which was to his own interest, and as the manager went away remarked to the writer: "Under the old system there would have been a regular 'call down' about that."

Cutter and management soon learn that care and system profit more than haste. The cutters earning the best wage are those who begin at the right place, plan out the cutting to use the most of the shell, cut in rows, and take the time necessary to avoid mistakes. (Cf. Pls. XLIV, XLV, and XLVI.)

Under such a plan there can be no occasion for discharge. The cutter who lacks the intelligence, the aptitude, or the character to become a skillful cutter, even with help, must find the business unprofitable and seek employment in other lines for which he may be better adapted. The work passes naturally into the class of skilled labor, and the skillful do not have their proper earning diminished by an average rate which is lowered by the waste and scant production of the unskillful.

This report is not, however, concerned with the relative merits of systems of management except as they may affect the waste of raw materials. Propagation, protection, and the economical use of material are phases of the general conservation problem that are indissolubly linked. Without regard to the details of any system of administration, it may be said that the economic use of shells will necessarily be promoted by a plan (1) which divides between management and labor the responsibility for waste of shell; (2) which does this in such a way as to remove as far as possible the necessity for arbitrary docking or rebuke or discharge; and (3) which consequently substitutes for such forms of discipline a true spirit of cooperation between employer and employee for mutual advantage. The best spirit and the best intelligence of all concerned may well combine for the most advantageous use of materials, having in view both the diminution of waste and the improvement of quality of product. It is futile to imagine that in the long run the interest of cutter or manufacturer is promoted by waste or antagonism to legitimate improvement.

PROPORTIONS OF PRODUCT AND WASTE.

The unavoidable waste in the commercial use of mussel shells is remarkably high, assuming the most economical use possible of materials under present conditions. The waste involved in the combustion of coal is often cited as an example of unavoidable loss, where, under the most efficient methods in use, only a small per cent of the latent energy is converted into power. In button manufacture we find that only 5 to 8 per cent of the original gross weight of the mussel enters into the button product; but the remainder in this case is not all lost, since there are waste products which are utilizable at a less profit. In the first place, when the mussel is taken from the river, we find that about 3 per cent of the dry weight is thrown out as meat.[a] The losses in the shell at different stages of manufacture, as determined by averages from several specific tests made by J. B. Southall, are shown in the following table:

Losses in Shells of Certain Species During Manufacture of Buttons.

Waste or by-product.	Lake Pepin mucket.	Niggerhead.
	Per cent.	*Per cent.*
Discarded shell	60.8	73.6
Dust in sawing blank	16.9	8.8
Dust in grinding and finishing button	12.9	10.8
Total waste or by-product	90.6	93.2
Weight of buttons	9.4	6.8
Total	100.0	100.0

Roughly speaking, 7 per cent of the total weight of heavy shells like the niggerhead is marketed from the factory in a form worth $2.16 per pound,[b] while of the remaining 93 per cent, a portion is entirely thrown away and another portion sold as crushed shell, or dust, at a quarter of a cent per pound.[c]

The table and data are not of purely academic interest. They point to the significance of the problem of the utilization of the now unavoidably wasted material, and they emphasize the importance of putting more of the shell into the high-priced product, the buttons.

It remains to differentiate the instances of waste which are prevented by correct practice in cutting and those which arise from the form or character of the shell, and which consequently may be obviated only by new discoveries in method or by changing demands of the trade.

WASTE IN CUTTING.

It may be conceded that there is some waste which it would be possible but not desirable to avoid. Given the present economic conditions, it will appear that parts of the shell which could be cut are better left uncut, because the cost in labor

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[a] The proportion of dry meat to shell varies widely with the different species. It is safe to say, however, that, on the average, the meats with all water dried out represent one thirty-fifth of the total dry weight of the mussel. The utilization of the meats is discussed in part 2, page 61, on the mussel fishery.

[b] Figuring 1,248 buttons to the pound at 25 cents the gross (good quality 16 line).

[c] Price of crushed shell, $5.50 per ton. Price of dust, $4 per ton.

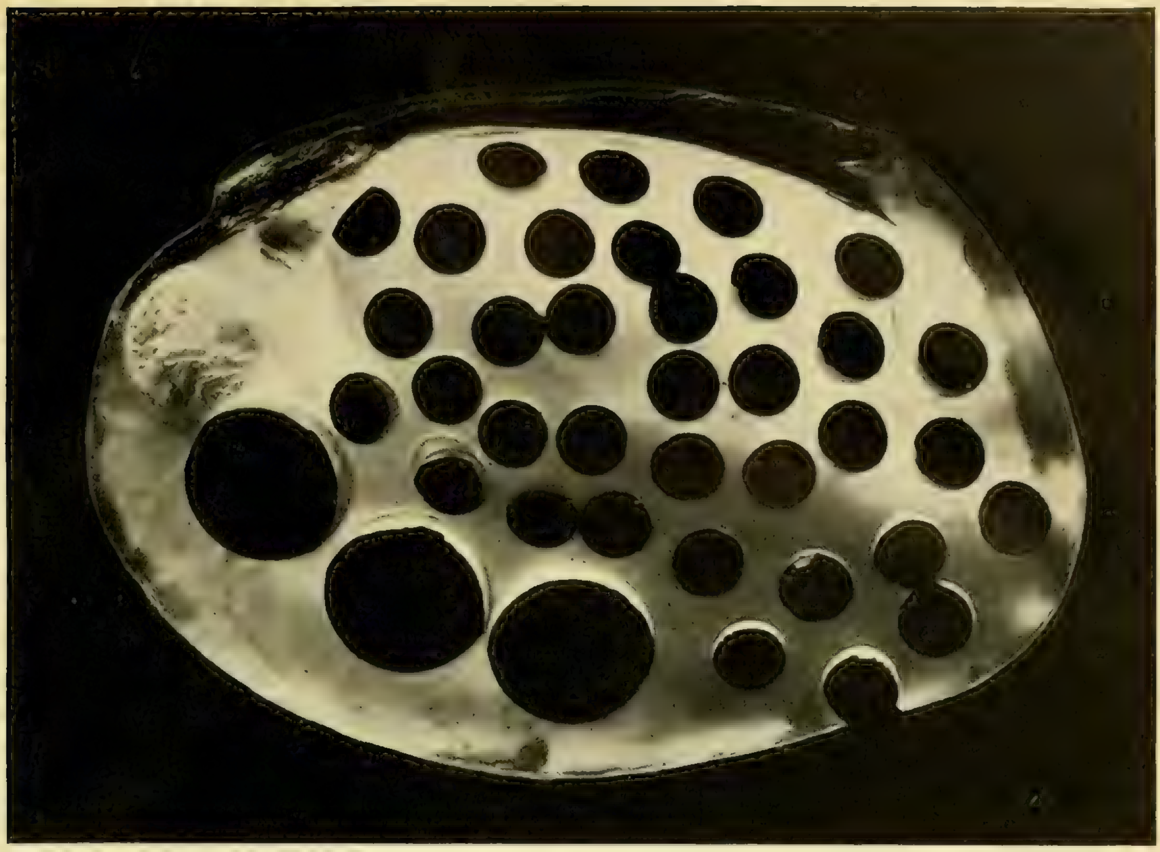


FIG. 1.—Poor cutting due to want of care or lack of experience. Note poor spacing, overlapping of blanks, and exposed margins of shell, indicating that blanks were pushed out. (See p. 87.)

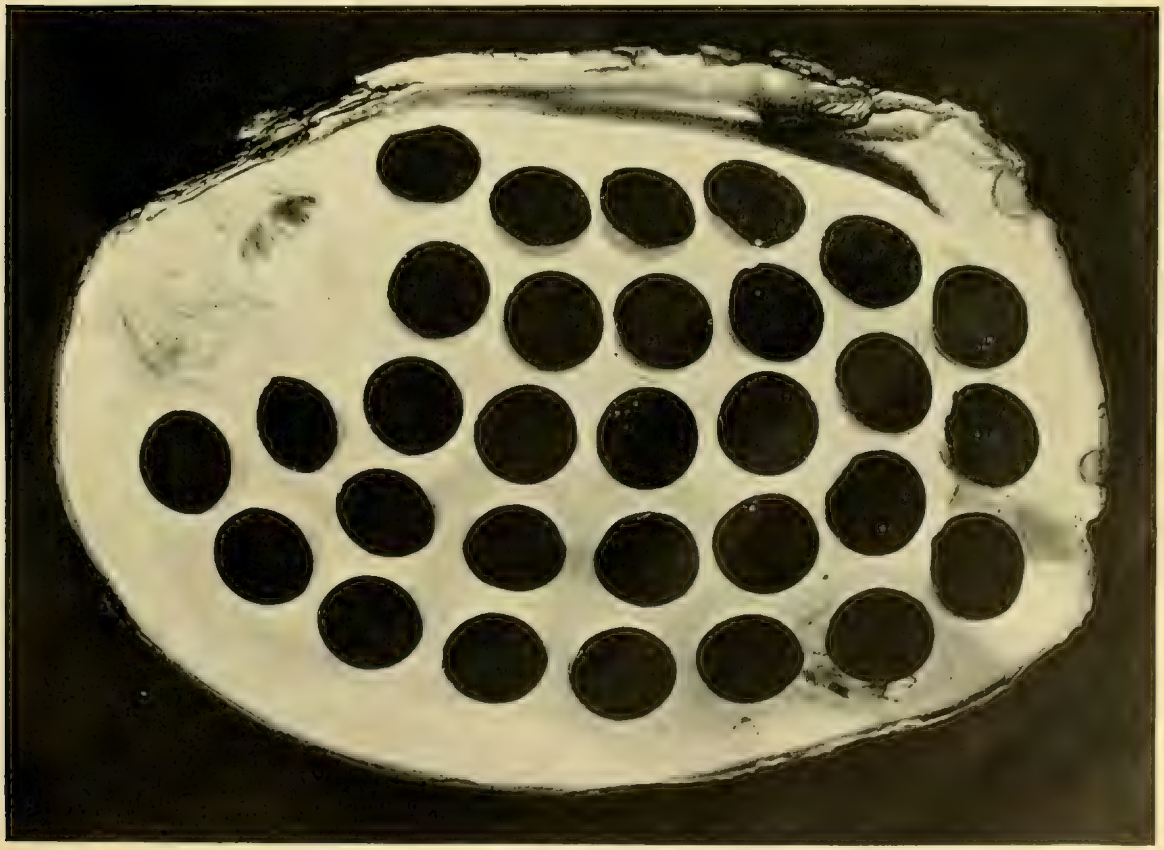
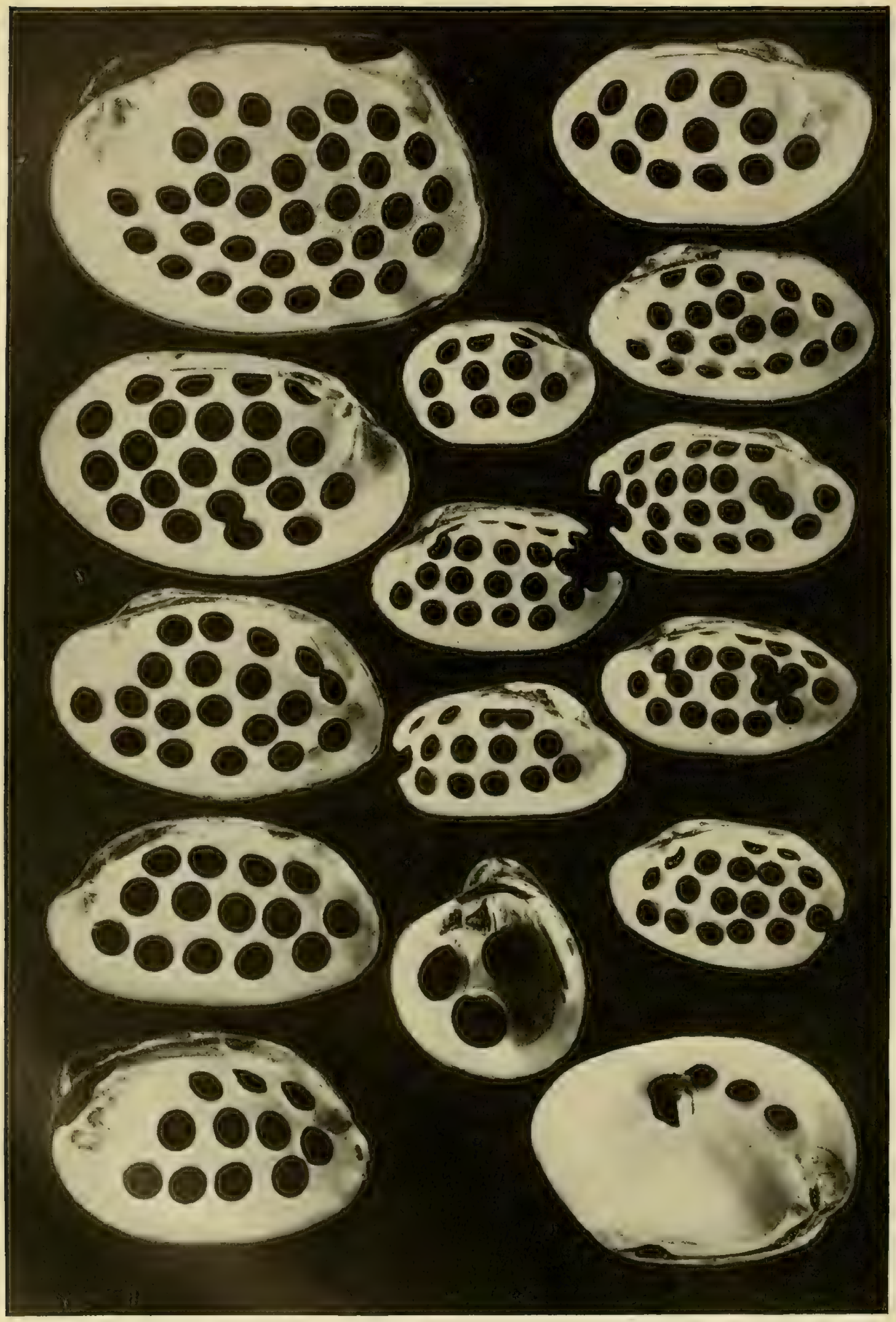


FIG. 2.—Illustrating careful, methodical cutting. (See p. 87.)



Illustrating reasonably careful practice in cutting. In endeavoring to cut too closely the shell in lower right-hand corner the saw was destroyed. (See p. 87.)

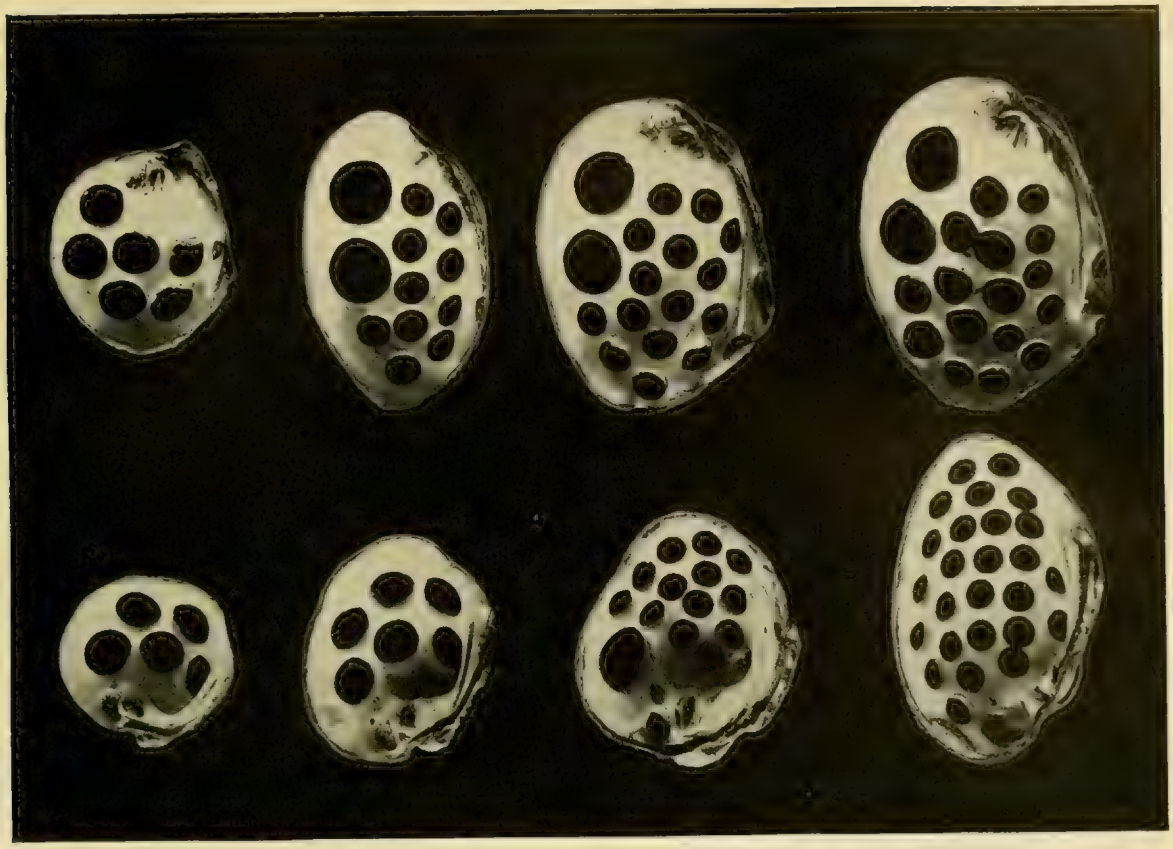
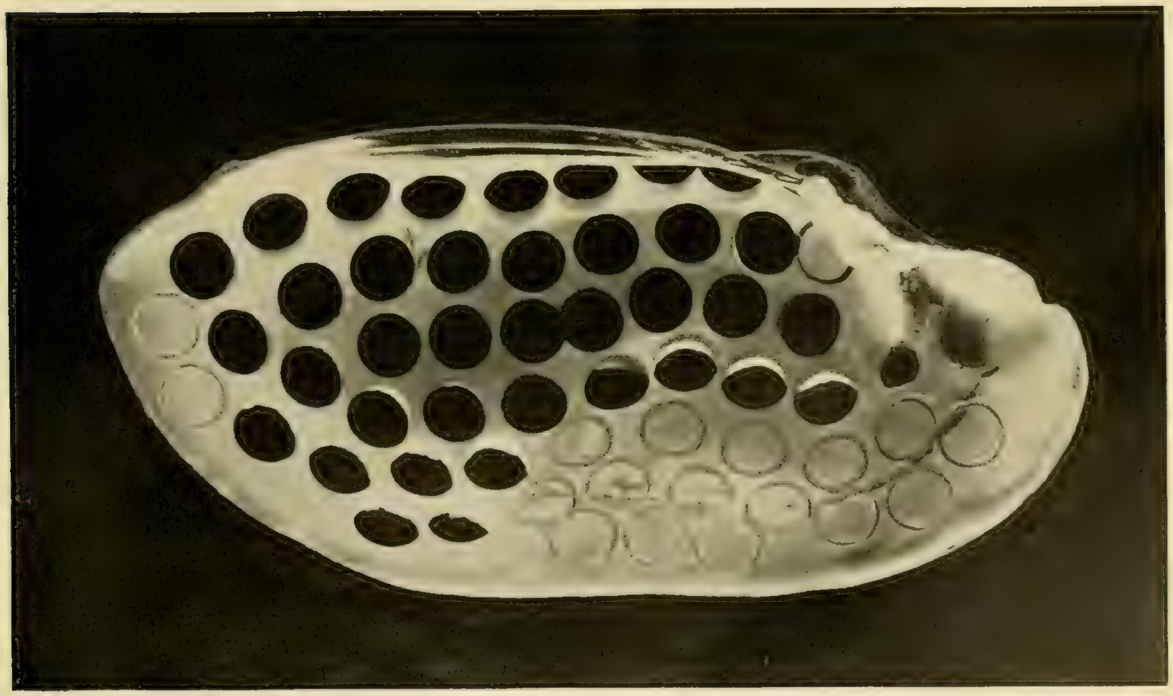


FIG. 1.—Illustrating economical use of shells of various sizes. (See p. 87.)



Illustrating theoretically correct use of shell for small blanks. (See p. 87.)

or in injury to machinery would more than counterbalance the saving of material. Nevertheless, all factories are not equally efficient, and some waste occurs that could be prevented by watchful and judicious management and by proper training of labor. It will not be out of place to illustrate this fact by the use of a few photographs with brief explanation.

Plates XLIV, XLV, and XLVI illustrate the progress in good cutting.

Plate XLIV, figure 1, shows a single shell where the cutter, though exerting some care to avoid waste of material, showed a lack of experience or judgment. The blanks were irregularly and poorly spaced. In some cases, too, the blanks were spaced too closely, so that true circular buttons could not have been obtained. Contrast this with the lower figure on the same plate, where the cutting was in rows, with best practicable use of shell.

Plate XLV includes shells from various plants where the cutting is done with more than average economy; the shell in the lower right-hand corner illustrates a danger in too close cutting, where, because of overlapping a space previously cut, the cylindrical saw was caused to unroll with more damage than a slight loss of material would have entailed. The shell was evidently thrown away in disgust. The avoidance of the rim blanks in the heavier shells of this illustration may be noted. Blanks obtained from the rim of such shells have so much bevel that they will not work successfully in the further processes and are liable to cause injury to machinery.

Plate XLIV, figure 2, and Plate XLVI illustrate the most economical cutting feasible under present conditions, and also show how shells are used to practical advantage by double cutting; that is, by taking out the larger lines first and then removing the smaller lines. Plate XLVI, figure 2, shows an excellent spacing of blanks in a very favorable shell.

WASTE DUE TO EXCESSIVE THICKNESS.

A serious source of waste is found in excessive thickness of shell. If a shell is of sufficient thickness for buttons throughout, and in no part of excessive thickness, the waste consists in the spaces between blanks and the unutilizable portions of shell such as the hinge, umbones (knuckles), and rim. Many otherwise excellent shells, however, are very thin at the tips, while the blanks from the forward portion of the shell are so heavy that from one-half to three-fourths or more of the thickness must be ground off (Pl. XXXVII, fig. 2). It is unfortunate that such blanks can not be split. Very thick blanks from ocean-pearl shells may readily be sliced or split into as many blanks as desired; but in the fresh-water mussel shells there are irregularities of stratification, or faults, in the shell which cause the splitting to occur in such irregular fashion that with any method or device so far employed the waste is quite out of proportion to the saving.

Between shells which produce 700 gross of buttons per ton and those which produce 1,000 gross per ton there is a distinct difference in economic value, assuming quality to be the same; also, there is a saving in the working of lighter shells, since there is evidently a useless waste of time involved in the sawing of thick shells and in the subsequent grinding away of excessive thickness. Furthermore, the heavy shells are of much slower growth. Assuming an equal quality from shells which are lighter and more nearly uniform in thickness, there will be a quicker return from efforts at propagation of such species and a greater likelihood of being able to maintain the supply.

There will undoubtedly develop a more insistent demand for the best yielding material, causing an advancing price, while the shells which are found to work with less economy will decline (relatively) in price to a point where they can be used with actual profit.

WASTE IN DISCARDED SHELLS.

A discussion of the general subject of economy would not be complete without reference to the discarding of certain classes of shells which have some good qualities, but which for one reason or another are not suitable. In the very beginning it was thought practicable to use only shells of comparatively uniform thickness. Accordingly, muckets and sand-shells were bought, while niggerheads, pimple-backs, etc., were refused. It was not long before the excellent qualities of these shells became apparent, and it was found practicable to cut them.

The discards at the present time are almost exclusively shells which could not yield buttons for which there is a market. Such are thin shells, colored shells, and shells exceedingly stained and spotted; not all of these are wasted. Some pink and purple shells, when thick enough, are found to be of a particularly good working quality; they can be used for making the smoked-pearl buttons by staining with silver nitrate. The demand for such buttons is limited, and, as many pink or discolored buttons are cut incidentally and culled from the better grades, there is little actual market for the pink shells beyond the limited requirements of the novelty trade. The elephant's ear is a rather common shell of beautiful pink, purple, or salmon color, and it is said to be superior in working qualities to the better grades of white shells. It is unfortunate that a simple, satisfactory method of bleaching has not been available or that there is no market for the natural pink and purple buttons produced from it. Many discolored shells may be bleached, though somewhat imperfectly, but bleaching methods have been greatly improved in recent years.

The discoloration is generally attributable to disease or parasites. Discolored shells seem to be more common in sluggish water and in portions of streams polluted with sewage.

RÉSUMÉ OF MANUFACTURE.

The fresh-water shells are used preeminently in domestic button manufacture, though a small proportion enters into the producton of novelties, and up to 1914 an increasing number were being exported both for novelty and button making.

The process of button manufacture consists in classifying and soaking or moistening shells, cutting (either in detached cutting plants or in a room of the complete factory), cleaning, tumbling, backing, and soaking the blanks, facing and drilling (in one or two automatic machines), cleaning, polishing, drying and sorting the buttons, and finally sewing them upon the cards or packing in bulk. Processes of bleaching and of staining may be introduced as desired.

The principal operations of skill are the cutting of blanks and the sorting of buttons. The chief desiderata are the perfection of an automatic cutting machine and the elimination of waste as far as practicable at all stages. These needs are receiving the careful attention of many manufacturers and mechanics. Remarkable improvements in button-making machinery and systems of management have taken place in recent years. Perhaps conspicuous advances in the future may be made, not only in such improvements of management and existing machinery as are always to be expected, but in the invention of an efficient machine for blank splitting and in the perfection of bleaching processes; also in the greater utilization of unavoidable waste.

In 1912 there were 196 separate plants employing mussel shells in manufacture. Of this number 153 plants were devoted to cutting only, while 36 factories engaged in finishing and grading. Of these latter 20 included cutting rooms, also, and thus comprised all the processes of manufacture. In addition there was a single branch plant devoted exclusively to the grading of buttons. There were 34 shell-crushing plants, of which 32 were connected with button factories, and there were 6 novelty works. These establishments were located in 20 States as follows: Alabama, Arkansas, Kansas, Kentucky, Illinois, Indiana, Iowa, Maryland, Massachusetts, Michigan, Minnesota, Missouri, New Jersey, New York, Ohio, Oklahoma, Pennsylvania, Tennessee, West Virginia, and Wisconsin.

The industry is peculiarly American. The material has until recently been obtained in no other country, and the machinery and methods are largely of American design and development.

LIFE HISTORY OF THE BLUE CRAB

By E. P. Churchill, Jr.
Assistant, U. S. Bureau of Fisheries

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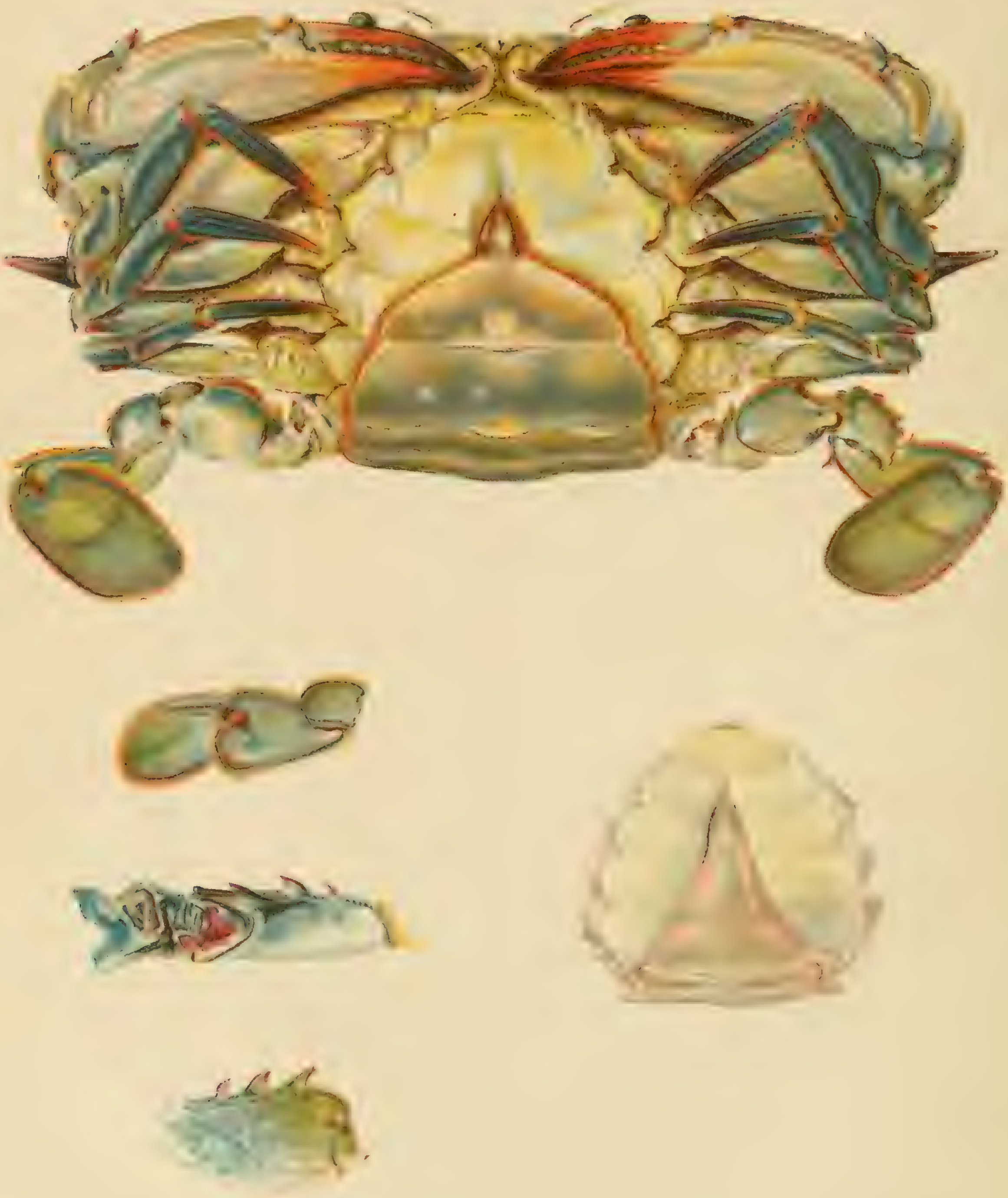

Coloration of the Crab in Molting Stages.

BREUKER & KESSLER CO. PHILA.

LIFE HISTORY OF THE BLUE CRAB.

By E. P. CHURCHILL, Jr.,
Assistant, United States Bureau of Fisheries.

NAME.

The crab commonly used as an article of food on the eastern coast of the United States belongs to the species known as *Callinectes sapidus*.[a] This name may be freely translated as "savory graceful swimmer." Those who have eaten this crab in either its hard or its soft-shelled state can give ample testimony that the term "savory" is well applied. It is known generally as the blue crab from the fact that considerable blue color is usually found on its upper surface, especially on its claws. In Chesapeake Bay regions, where it forms the basis of an extensive crabbing industry, it is referred to simply as the "crab," other species of crabs having some common distinctive name, as the "fiddler," "sea spider," etc.

The blue crab belongs to the family known as Portunidæ, or swimming crabs, from the fact that the posterior pair of legs, or back fins, are flattened for use in swimming. All crabs of this family, in which the abdomen, or apron, of the male is ⊥-shaped, belong to the genus Callinectes. The species *Callinectes sapidus* includes only the edible, or blue, crab of the Atlantic coast of the Americas.

HABITAT AND DISTRIBUTION.

The blue crab is found on the Atlantic coast from Massachusetts Bay to at least as far south as the northern part of South America. In the United States it is common from Massachusetts to the southern extremity of Texas.[b]

Although occurring at most points on that part of the coast, it is especially abundant in the bays and mouths of the rivers. It is found during the summer in relatively shallow water but at greater depths during the winter. Although its natural medium is salt water, instances are known in which specimens have been found in brackish,[b] and even in fresh, water.[c]

The adult crabs tend to remain in deep water, but the young, especially, come inshore to a point where the water is only a few inches in depth. In general, the closer inshore the observations are made, the smaller the size of the crabs found.

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[a] This name was established by Dr. Mary J. Rathbun in The Genus *Callinectes*. Proceedings, U. S. National Museum, vol. 18, 1895. Washington, 1896.

[b] Hay, W. P.: The Life History of the Blue Crab (*Callinectes sapidus*). Report of the U. S. Bureau of Fisheries, 1904, p. 400. Washington, 1905.

[c] A crab dealer of Hampton, Va., related to the author that he found numerous crabs in Back Bay, Va., on Nov. 15, 1917, the water there being fresh enough to drink.

The blue crab is especially abundant in Chesapeake Bay. This body of water is of sufficient size to afford a breeding ground for an immense number of crabs. The young are very abundant in the region extending from the vicinity of Tangier Island, Va., to Baltimore, Md., the bottoms underlying the shallower waters of this part of the Bay forming, during the summer, a ground especially suited to the growth and molting of the maturing crabs. In the deeper waters of the southern part of the Bay the adult crabs lie on the bottom in vast numbers throughout the winter months. During the summer they frequent the more shallow waters, where they spawn in great abundance.

DEVELOPMENT OF THE YOUNG.

The young of the crab are hatched from eggs (Pl. XLVIII, figs. 1 and 7, and Pl. LII, fig. 30), which measure about 1/100 of an inch in diameter,[a] not as large as the period at the close of this sentence. When first laid, the eggs are yellow or orange in color, due to the color of the yolk granules within them, which serve as food for the young as development proceeds. As the eggs near hatching, this color disappears, and, since the eyes of the young are comparatively large and are of a very dark color, the mass of the eggs appears almost black.

As the eggs are extruded from the body of the female they become attached to the fine hairs of the swimmerets on the under side of the abdomen. There are no swimmerets on the anterior segment of the abdomen, but there is a pair each on the second, third, fourth, and fifth segments, and none on the sixth or seventh. There are thus eight swimmerets in all, four in a row on each side. Each swimmeret is made up of two branches, an inner and an outer (Pl. XLIX, fig. 16). The hairs borne by the inner are much finer and longer than those on the outer, measuring in diameter from 1/200 of an inch at the base to 1/700 at the middle.[b] The eggs all find lodgment on and are carried entirely by these hairs of the inner branches of the swimmerets, but never by the outer. Microscopic examination of these hairs, when they are bearing eggs, shows that each hair is covered throughout almost its entire length with a thin coating of a semitransparent material of a faintly yellow color. Each egg is attached to this covering by a separate short tendril of the same material, the hair and its burden resembling a long thin stem, with a great number of berries attached to it by short tendrils (Pl. XLVIII, fig. 7, and Pl. LII, fig. 30). From this resemblance, the crab, when bearing eggs, is sometimes said to be "in berry" or "berried."

There are eight tufts, or clumps, of eggs, corresponding to the eight inner branches of the swimmerets. These tufts are so large, however, that they are all crowded together, so that there is formed a flattish mass about 3 inches wide by 2 long by 1¾ deep, and fairly smooth in contour (Pl. L, fig. 19, and Pl. LI, fig. 22). From its general appearance and color, this mass is known commonly as a sponge, orange, lemon, punk, or ball.

The egg color is yellow or orange when first laid, but, as already stated, it becomes almost black as hatching time approaches. The abdomen is pushed back by the sponge until it extends almost in a straight line with the body, except at the posterior end, where it curls downward behind the mass of eggs.

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[a] The measurement given in this text was made by the author. The size is placed at 1/108 of an inch by F. H. Herrick in Natural History of the American Lobster. Bulletin, U. S. Bureau of Fisheries, Vol. XXIX, 1909, p. 310. Washington, 1911.

[b] Herrick's op. cit., p. 310.

The number of eggs contained in a sponge of average size is enormous. S. I. Smith places it at 4,500,000,[a] which number was quoted by Herrick.[b] Paulmier[c] estimates that between 2,000,000 and 3,000,000 eggs are borne in the sponge. The present author found that by actual count there are about 200 eggs upon each hair of the swimmeret. The hairs occur in fairly regular bundles of about 5 each, there being about 20 bundles in each of the 11 rows, arranged in a longitudinal manner, on the swimmerets. There are 8 swimmerets. Computing these figures gives the sum of 1,760,000. It must be borne in mind that this figure is not much more than an estimate, as it is next to impossible to determine accurately the number contained in such a large mass of objects as minute as the eggs in question. The most accurate statement that can be made is that there are from 1,750,000 to 2,000,000 eggs in a sponge of the usual size.

The eggs had been fertilized while in the body of the female. This process is described on page 117.

The eggs are carried upon the swimmerets while their development goes on, or during what might be termed the "period of incubation." About 15 days are required for the eggs to hatch. A female crab was kept under observation in a float (Pl. LI, fig. 20, and Pl. LV, fig. 37).[d] On June 15 this individual threw out a sponge. On June 29 it was found that some of the eggs had hatched, since there were many empty shells upon the swimmerets. By July 2 nearly all the young had hatched out and left the mother. In this case it will be seen that the period of incubation was from 14 to 17 days. Another crab was observed to spawn on August 15. The eggs hatched within 12 to 15 days. The temperature of the water, no doubt, has some effect upon the duration of the incubation period. During the last of June, when the first experiment was being carried on, the temperature of the water was about 79° F. During the August experiment the water was about 85° F. This may account for the fact that the eggs hatched somewhat more quickly in the latter than in the former case.

It has been thought by some that the young crabs cling to the swimmerets of the mother for a time after hatching. Binford,[e] however, observed the young as they hatched from two females and found that this was not the case. The present author, in the case of the two crabs used in the experiments just described, found that the shell of the egg split into two parts (Pl. XLVIII, fig. 5), the young crab emerged and, after freeing itself from a thin membrane which covered it, swam away. Numerous empty split shells (Pl. XLVIII, fig. 10, and Pl. LII, fig. 30) were found on the swimmerets of the adult, but no young crabs were observed clinging there. Several other crabs were observed as the eggs were hatching, but in no case were any young found clinging to the swimmerets.

It is thought by many that the young, immediately upon hatching, turn about and devour the mother crab. Needless to say, this idea is a mistaken one, although, of course, quite small crabs feed upon and may even consume any dead crab which they chance to find. In fact, this erroneous notion arose from the occasional observation of a dead sponge-bearing crab being surrounded and devoured by a multitude of young crabs about the size of the fingernail and the assumption that these young had just hatched from her sponge and then turned about and were devouring her. From the description, given in the following paragraph, of the young immediately after hatching, it will be seen that it would be impossible for them to devour a hard-shelled adult crab, even though observation were lacking to disprove the notion.

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[a] Smith, S. I.: Report on the Decapod Crustacea of the Albatross Dredgings. Report of Commissioner of the Fish and Fisheries for 1885, pp. 618–619. Washington.

[b] Herrick; op. cit., p. 309.

[c] Paulmier, F. C.: The Edible Crab. 55th Annual Report, N. Y. State Museum, 1901, p. 134.

[d] Unless otherwise stated, all of the experiments discussed in this paper were carried on at Hampton, Va., between October, 1916, and October, 1917.

[e] Binford, R.: Notes on the Life History of *Callinectes sapidus*. Johns Hopkins University Press, February, 1911, p. 1.

The young of the blue crab, after hatching, pass through two stages before assuming the true crab shape.[a] In the first stage a young crab is known as a zoëa. The zoëa is virtually microscopic in size, measuring about 1/25 of an inch in length. From Plate LI, figure 21, it will be seen that in this stage the crab is much unlike the adult form. The body is somewhat cylindrical in shape, the eyes large and conspicuous, the spines at the sides short; there is a long curved spine on the back; the claws are lacking; and the abdomen is long and round, ending in a sort of forked tail. The zoëa has a long, sharp beak, two pairs of antennæ, and four pairs of leglike appendages. The true legs have not yet appeared. The zoëa swims backward by very rapidly jerking the abdomen up against the lower side of the body. The crab in this stage is free-swimming and does not crawl over the bottom, as it does in the later stages. The zoëa increases in size only when it molts. At the present time, however, it is not known how many moltings occur before the second stage is reached.[b] At each molting the new form resembles a little more closely the next stage.

The crab in the second stage is known as a megalops (Pl. LI, fig. 23). It is still very small, being less than 1/25 of an inch in width. The megalops more nearly resembles the adult, having a rather flattened body and an abdomen shorter and wider than that of the zoëa. The eyes, however, are as yet more prominent than in the adult, and the two posterior legs are not flat, but rounded, and each is provided with a sharp point. The abdomen is not curled against the under side of the body, as is the case in the adult. The megalops swims freely and, also, may walk on the bottom. It is as yet unknown how many times the megalops molts before taking on the true crab shape. Smith and Hyman (op. cit.) found that, in the case of the rock, the green, and the fiddler crabs, there is only one megalops stage, the first megalops molting directly into the first crab stage. It is quite probable that this is true also of the blue crab.

Whether or not this is the case, there does come a molting at which the megalops suddenly assumes a shape very similar to that of the adult, except that the width of the body is not much greater than the length, and the eyes are borne on larger and thicker stalks. This creature may be called the first crab. The crab, as well as the preceding forms, increases in size only at the time of molting. Up to the present time no one has observed a crab as it passes through all the different molts involved in its life history. Certain stages, however, of the lives of several different crabs have been observed, so that a fairly accurate estimate can be made of the number of moltings which occur and the time required for the crab to reach the adult stage.

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[a] The description of the first two stages of the young crab is abridged from the Handbook of Invertebrate Zoology, W. K. Brooks, published by S. E. Cassino, Boston, 1882.

[b] Paulmier, op. cit., p. 135, estimates the number of moltings to be probably six, but gives no data upon which to support his claim.

Smith, S., in The Invertebrate Fauna of Vineyard Sound, U. S. Fish Commissioners' Report, 1873, found that there are four zoëal stages in the green crab of the Atlantic coast.

Hyman, O. W., in a yet unpublished paper found that the fiddler crab passes through five zoëal stages.

Dr. Binford observed a crab which was kept in an aquarium while it passed from the megalops stage to that of the sixth crab stage.[a] The following table sets forth the results:

TABLE A.

Date molted.	Stage.	Width after molting.	Increase.
		Inch.	*Inch.*
July 18	Megalops	0.04	....
July 19	First crab	.128	0.088
July 27	Second crab	.196	.068
August 1	Third crab	.260	.064
August 6	Fourth crab	.348	.088
August 12	Fifth crab	.456	.108
August 25	Sixth crab	.516	.060

This crab was caught in its natural habitat while in the megalops stage and placed in the aquarium on July 18. It changed to the first crab on the next day. The zoëa and megalops stages, therefore, were completed by about the middle of July. In the region of Beaufort, N. C., where this experiment was carried out, the bulk of the young hatch during June; therefore, probably not more than one month had elapsed between the hatching of this specimen and the time of confinement in the aquarium. That is to say, not more than a month was required in which to complete the zoëa and the megalops stages.

The author succeeded in carrying several crabs through certain of the molting stages between the sixth crab and the adult. Some of the crabs were kept in floats, but most of them were confined in cages of quarter-inch mesh wire (Pl. LV, fig. 38). These were placed on the bottom, in the water of Hampton River, at a depth of 4 or 5 feet at low tide. Each cage was equipped with a strand of wire by which it was lowered and raised and which was attached at its upper end to a stake. Although it was impossible to carry a particular crab through its entire life cycle, by beginning the experiment with crabs of different sizes, the author was able to collect data, from which it is possible to estimate how many moltings occur as the crab develops from the sixth crab stage to the adult size. It must be kept in mind that at this time of life the successive stages of the crab are very similar, except in size. This last also varies with the individual, the temperature, etc., so that it can not be ascertained by examination in just which stage a particular crab is. The best that can be done is to try to form as accurate an estimate as possible of the number of times a crab usually molts while reaching adult size and the time required to attain maturity.

The results obtained by the author are presented in Table B.

---

[a] Binford, op. cit., p. 2.

TABLE B.

Individual and sex.	Width.		Increase.		Time between molts.
	Before.	After.			
	Inches.	*Inches.*	*Inches.*	*Per cent.*	*Days.*
No. 1, male	0.437	0.562	0.125	28	17
No. 2, male	.562	.812	.250	44	(a)
	.812	1.000	.187	23	13
No. 3, female	.750	(b)	....	....	(a)
	(b)	1.000	....	....	11
	1.000	1.250	.250	25	10
No. 4, female	1.062	1.375	.313	28	(a)
No. 5, female	1.375	1.687	.312	29	(a)
	1.687	2.250	.562	33	16
No. 6, male	1.750	1.937	.187	10	(a)
	1.937	2.500	.562	29	26
	2.500	3.125	.625	25	20
	3.125	4.312	1.187	38	21
No. 7, male	4.250	5.500	1.250	29	(a)
No. 8, male	5.500	7.000	1.500	27	(a)
No. 9, female	1.687	2.125	.437	25	(a)
	2.125	2.750	.625	29	14
	2.750	3.750	1.000	36	25
No. 10, female	2.500	3.062	.562	22	(a)
	3.062	4.062	1.000	32	23
No. 11 [c]	1.437	1.687	.250	17	(a)
	1.687	1.937	.250	14	27
No. 12 [c]	2.000	2.250	.250	12	(a)
	2.250	2.937	.687	30	24
No. 13, female	1.562	1.937	.375	24	26
No. 14, female	3.500	4.500	1.000	28	(a)
	4.500	5.750	1.250	36	42
No. 15, female	4.750	6.000	1.250	38	(a)

[a] The interval between molts is unknown, since this is the first molting in captivity.

[b] No record.

[c] Sex unknown.

From the data here given, combined with those furnished by Binford's results (Table A), it is possible to work out a table showing the number of moltings, the successive sizes of the stages, the percentages of increase, and the intervals elapsing between moltings of the crab while passing from the last megalops stage to the usual adult size. Such a table follows.

TABLE C.

Stage.	Width.	Increase.		Intervals between molts.
	Inches.	*Inches.*	*Per cent.*	*Days.*
Megalops	0.04			
First crab	.128	0.088	220	
Second crab	.196	.068	53	8
Third crab	.260	.064	32	5
Fourth crab	.348	.088	33	6
Fifth crab	.437	.089	25	6
Sixth crab	.562	.125	28	17
Seventh crab	.812	.250	44	11
Eighth crab	1.062	.250	30	13
Ninth crab	1.375	.313	29	10
Tenth crab	1.687	.312	22	[a] 15
Eleventh crab	2.250	.563	33	16
Twelfth crab	3.125	.875	38	20
Thirteenth crab	4.312	1.187	37	21
Fourteenth crab	5.500	1.188	27	[a] 25
Fifteenth crab	7.000	1.500	27	[a] 35
Average increase (first to fifteenth crab stages)			32.71	[b] 14.85

[a] Estimated.

[b] Total time, 208 days, or 6.9 months.

It will be seen that, according to this table, 15 moltings occur. It is probable that the number is not absolutely fixed, but that it varies somewhat with the individual crab, usually being about 15. The size and rate of growth of individual crabs vary so that not all reach the width of 7 inches. No doubt, however, as many moltings occur, on the whole, in the smaller specimens as in the larger, the individual being smaller at the start and the actual increase in size at each molting being less. Various factors, such as temperature, food, etc., certainly affect the growth rate. Ninety-six adult female crabs were measured, and the average width was found to be 6.117 inches. No similar records are available for the male, but the average width is probably about 6.5 inches at least. Individual specimens of males are found which are much greater in width than this. Two exceptionally large specimens were measured, one of which proved to be 8 inches in width and 20 inches from tip to tip of the extended claws, and the other 8.5 inches in width and 1.25 pounds in weight. Specimens of females 7 inches in width are occasionally seen.

The average increase in width at each molting is 32.71 per cent, or about one-third. This does not include the change from the last megalops to the first crab stage, at which time the increase in width is over 200 per cent, owing to a material change in the form of the animal. The increase from the first crab stage to the second is over 50 per cent. At the subsequent moltings the increase varies from 22 to 44 per cent, usually being about 33⅓.

The time elapsing between molts is less in the early stages than in the later, averaging 6 days during the first 4 stages, 13 during the next 6, and 25 during the last 4. The average for all the stages is nearly 15 days.

The results above set forth are confirmed by data obtained from some unpublished notes which were kindly placed at the disposal of the author by Prof. Hay. Hay observed the molting of 22 immature crabs which were confined in floats on the water at the United States Fisheries biological laboratory at Beaufort, N. C., during the summers of 1913, 1914, and 1915. These crabs ranged from 1.0625 to 6 inches in breadth. His results are summarized in the following table:

TABLE D.

Individual crab.	Width.	Gain.	Days between molts.
	Mm.	*Mm.*	
1	[a] 27 to 35	8	15
2	31 to 38	7	11
3	31 to 38	7	11
4	35 to 45	10	12
5	53 to 70	17	19
6	55 to 71	16	21
7	55 to 73	18	12
8	57 to 76	19	21
9	59 to 77	18	16
10	62 to 78	16	24
11	62 to 84	22	23
12	63 to 85	22	19
13	63 to 83	20	20
14	64 to 82	18	27
15	69 to 88	19	31
16	72 to 98	26	26
17	73 to 99	26	23
18	80 to 98	18	28
19	80 to 105	25	32
20	82 to 102	20	31
21	90 to 116	26	29
22	[b] 118 to 155	37	33

[a] 1.0625 to 1.375 inches.

[b] 4.625 to 6 inches.

It will be seen from this table that the gain varies from 7 or 8 millimeters in the first stages to from 26 to 37 for the last. The gain is about one-third in 15 of the cases and one-fourth in the other 7. The interval between moltings varies from 11 days for the earlier to about 30 for the later stages. The average for the first 11 cases is 16 days and for the last 11 cases 28 days.

The total time required for the hypothetical crab of Table C to reach maturity from the megalops stage is 208 days, or nearly 7 months. Allowing a month (see Binford's results) for the completion of the zoëa and megalops stages, it will be seen that about 8 months would be required for the crab to reach adult size after hatching. All the evidence at hand, however, leads to the belief that the crab does not molt during the winter months. Perhaps the best evidence for this is the fact that, even before the close season was established in Maryland, the soft-crab industry ceased some time in October of each year until the middle or last of the following April. As this industry is dependent on the securing of molting crabs, they either do not molt during the winter or retire for the process to water of such a depth that access can not be had to them by the scrapes used in securing molting crabs nor by the oyster dredges.

Adult crabs which were kept in floats were found to become sluggish and to take no food after the temperature of the water fell to about 50° F. A juvenile crab, No. 6 of Table B, was secured on February 25 and kept until April 20 in the laboratory, where the temperature of the water in the aquarium varied from 44° to 55° F. No moltings occurred. Other experiments, carried out during the summer, proved that crabs will molt freely in aquaria in the laboratory. Binford's work also shows the same to be true. On April 20 this crab was placed in a float in the water of the bay, the temperature of the water being 60° to 65° F. On May 5 the crab molted. Very probably crabs do not molt during the season when the temperature of the water is less than 60° F. From temperature records of the water of Chesapeake Bay, kept throughout the year, it has been found that between about the last week of October and the middle of April the temperature of the water is below 60° F.

The bulk of the young crabs of Chesapeake Bay hatch during the last two weeks of June and the earlier part of July. From that time until the last part of October four months elapse. During this time the crabs pass the first two stages and reach probably about the ninth or tenth crab stage, attaining a width of about 1.25 to 1.50 inches. Then come the winter months, during which time the crabs most probably do not molt, but lie dormant on the bottom. Growth and molting are resumed about the middle of April or the first of May. During the next three and one-half or four months the crabs molt five or six times and reach maturity during the last part of July or in the month of August. This agrees with the fact that during the six weeks from the middle of July to the last of August most of the pairs of mating crabs are found. As is described more fully on page 104, this occurs in the female at the time of the last molting and is thus a sure index of her arrival at the adult stage.

The best evidence we have, then, points to the probability that the crab reaches the adult stage about 13 or 14 months after hatching. If, for example, a crab is hatched during June, it will reach the adult stage and mate during the latter part of July or the month of August of the following year.

After leaving the megalops stage the abdomen of the male assumes the characteristic ⊥ shape, which is found throughout the remaining term of his life. The abdomen is broad at the line of attachment with the body, but curves in shortly to a narrow portion (Pl. LIV, fig. 35), which lies in a groove in the middle of the lower side of the body. Plate LIV, figure 34, represents the adult male crab when viewed from above.

The abdomen of the female, after she leaves the megalops stage, is broad at the base of attachment and tapers to a point, each side forming almost a straight line (Pl. LIII, fig. 32). It lies in a depression on the lower side of the body and is held quite firmly in place by a pair of hooks which project from the body into cavities in the sides of the abdomen. This form of abdomen is found in each stage of the female until adult size is reached. At the molting from which the crab emerges as an apparent adult the abdomen changes to almost a semicircular shape, except for a small point at the tip (Pl. LIII, fig. 33). It no longer lies in a depression of the body, and there are no hooks. It is held against the body by the effort of the muscles alone. The swimmerets seen on the under side of the abdomen, when it is pulled away from the body, are large and conspicuous (Pl. XLIX, fig. 16). In the pointed form these are small and insignificant in appearance. Plate LIII, figure 31, gives a view of the adult female when seen from above. It will be noted that the body is relatively longer from beak to abdomen than that of the male and that the claws are smaller. The adult male can usually be distinguished from the female by these characteristics without the necessity of examining the abdomen.

It is most probable that this molting, in which the change in the abdomen is involved, is the last one which the female undergoes. Adult females were kept under observation for several months in crates and floats. None was observed to molt during this time. Immature crabs molted when kept under similar circumstances. In the region of Crisfield, Md., the center of the soft-crab industry, hundreds of thousands of crabs are caught shortly before molting and kept until it occurs, in order to secure the soft crabs for the market. The author examined 2,624 cast shells obtained from various ones of the floats in which such crabs are confined. Not one of these shells bore the broad abdomen of the adult female. No crabber was found who could recall ever having seen a cast shell bearing the broad abdomen. Females with broad abdomen are virtually never found exhibiting the easily recognized marks that distinguish a crab which is preparing to molt. Three crabbers were found who said they had seen one or two adult females bearing such marks, but that they did not molt when kept in the floats. It is very doubtful if the marks observed on the crabs in question were really the same as those that characterize a crab in the premolting stage.

As no such change occurs in the abdomen of the male, we have no criterion other than that of size, general appearance, and the manifestation of sexual activity by which to judge its probable state of maturity or whether it molts again after reaching maturity. The average maximum size is, as stated above, about 6½ to 7 inches. It is probable that the males become sexually active somewhat before attaining the maximum size, although the evidence on this point is rather meager. Both male and female crabs are found, especially during the winter, whose shells are discolored and bear barnacles, oysters, etc., apparently giving evidence that the shell has not been cast for a considerable period of time. There is no especial reason to suppose that the male molts indefinitely, in contradistinction to the female, which most probably does not.

MOLTING.

As already stated, the crab increases in size only when it molts, or sheds its shell. It is not exactly true to state that the crab grows only when it molts or that it grows by molting. It molts because it has grown and the shell, being inelastic, is too small and is thrown off.[a] Thus there is a sudden abrupt increase in size due to the expansion of the organism which has previously been crowded and somewhat wrinkled up within the old, hard shell.

The actual molting process has been described by Hay.[b] His excellent photographs illustrating some of the stages of the process are included in the plates appended to this paper. The account given in this paragraph is modeled to some extent after his description, although an effort has been made to present the matter in more detail than he employed. As the crab approaches the molting period it begins to show its condition by various external markings, or signs. The first indication is the appearance of a narrow, black line just within the thin outer and back margins of the two

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[a] Herrick, op. cit., p. 200.

[b] Hay, op. cit., p. 411.

outer segments of the swimming legs. In a day or two this line becomes white, and the crab is known as a green, fat, or snot crab. Within three or four days the line becomes pink or red. (See Frontispiece, upper small figure at left.) It is formed by the edge of the segment of the leg, which has become loose from the old shell about it and has produced a bright fresh one, which is visible through the thin, outer old shell. A crab bearing the pink or red line, sign, or ring will molt within two or three days and is known as a peeler or, more rarely, a sluffer. A set of fine wrinkles also makes its appearance on the blue skin between the wrist and upper arm of the claw. A reddish color begins to appear at the margins of the segments of the abdomen. The carapace, or black shell, and the top shell of the abdomen are naturally not continuous, and, when the moment of molting is at hand, the carapace begins to be lifted up slightly, so that a gap appears between it and the abdomen. Then, on the under surface of the carapace, a crack appears in the shell at each end of the gap just mentioned. As the carapace rises the crack on each side lengthens, passes below the spines, and extends nearly to the mouth. The posterior part of the body begins to protrude through the gap thus made. A crab in such a condition is known as a "buster" (Pl. LII, fig. 25). At this time it usually lies motionless, but can swim quite actively if disturbed. The remainder of the molting process requires only a few minutes, usually about 15. The carapace is lifted higher, the swimming legs begin to be withdrawn by rhythmic throbbing movements, and the body protrudes more and more from the shell (Pl. LII, fig. 26). The claws are the last to be withdrawn from the old shell, and, as they are large, some difficulty is involved in pulling them through the narrow arms of the claws. To obviate this, a roughly triangular portion of the shell of the large segment of the arm breaks along the outer side and rises up like a flap (Frontispiece, figure at lower left, and Pl. LII, figs. 26 and 27). The opening thus made extends along the arm to the body, and thus the natural opening for the connection of the muscles of the arm with the body is enlarged. Through this the large claw is drawn (Pl. LII, fig. 28). Immediately after molting is completed the skin is soft and wrinkled, and the spines are curved forward (Pl. LII, fig. 27). Although the crab is flabby and apparently helpless, it is capable of walking or swimming slowly if disturbed.

The spines soon become extended, and the shell fills out and begins to harden. A female crab was taken while in the buster condition and was placed in an aquarium in the laboratory, where it was allowed to complete the molting process. This crab measured 3.5 inches in width before molting. At 10.15 a. m., the instant after molting was completed, and at later intervals, the crab was measured. The results are summarized as follows:

Date.	Condition.	Hour.	Width.
			Inches.
July 12	Before molting	[a] 10 a. m.	3.500
Do	Just molted	10.15 a. m.	4.000
Do		11.15 a. m.	4.312
Do		2 p. m.	4.437
Do		2.30 p. m.	4.500
July 13	([b])	9.30 a. m.	4.500
July 14	([c])	9 a. m.	4.500

[a] Approximately. [b] Shell leathery, "buckram." [c] Shell nearly hard.

It will be seen that nearly all the increase in width, which amounted to 1 inch, was accomplished almost within the first hour after molting, and that, within 4¼ hours, the entire increase was completed. Within 24 hours the shell was too leathery to admit of the crab being used as a soft crab. A crab with such a leathery shell is usually called a buckram. Within 48 hours the new shell had almost reached the usual state of hardness.

Effect of the moon and tides.—It is a popular superstition that both the moon and the tides have a marked effect upon the molting of the crabs. It is supposed that at certain stages of the moon more soft crabs, or peelers, or whatnot, may be found than at certain other times. In the course of the experiments which were carried on in connection with the molting of crabs moltings occurred on the following dates in 1917: May 5; June 1, 12, 13, 19, 24, 26, 29, 30; July 2, 4, 9, 11, 12, 17, 21, 27, 31; and August 13, 20, and 23. In no case were there more than two moltings on any of the above dates, and usually only one. It would be difficult to establish any relation between the changes of the moon and the moltings observed in these cases. No evidence whatever exists for the belief that the moon has any effect upon the molting of the crab, and the matter may be dismissed as of a class with all folklore superstitions concerned with the supposed relation between the moon and mundane affairs, such as the weather, gardening, and the like.

In many places it is thought that there is a close relation between the rise and fall of the tides and the molting periods of crabs. Many persons claim that the young crabs molt at every tide or every two tides. This idea is shown at once to be erroneous, since at least 48 hours are required for the crab to reach the usual state of hardness after molting. The experiments with molting crabs, here described, were carried on where there was a tide of at least 4 feet. Some crabs were confined in floats which rose and fell with the water, others in wire cages resting on the bottom. No relation whatever was found to exist between the movements of the tide and the molting of the crabs.

The movements of the tides do affect the distribution of the crabs. Immature crabs especially tend to come in with the tide. Busters which thus come in with the water and soft crabs that have molted after coming in are rather inactive and slowly follow out the ebbing tide. For this reason the best time to find such crabs is on a "half tide," as it is falling. This, and other similar facts, have given rise to the notion that the movements of the tides actually hasten or delay or in some way regulate the molting act.

AUTOTOMY.

Closely connected with the process of molting is that known as autotomy, or the automatic throwing off of the appendages of the body. This phenomenon is common among crustaceans and has been the subject of considerable research. Little work, however, has been done in this line in connection with the blue crab.

If a crab is seized or held by a claw or leg, it often throws off the appendage and escapes. The break occurs across one of the segments near the body, there being an arrangement to prevent excessive bleeding. The crab is thus often enabled to escape with its life at the expense of an appendage. This latter loss is not always as serious as might appear as the power to regenerate the lost appendage is possessed by the crab, at least until the molting stages are completed. If the loss occurs shortly after a molting, the regeneration will be made at the next molting. If it occurs only a few days before a molting, the renewal takes place at the second subsequent molting.

In the process of regeneration a very small, white papilla, or protuberance, first forms in the end of the old stump. This papilla enlarges and becomes a sort of thin-walled sac in which the new appendage is formed. As the sac becomes larger the new appendage can be seen folded up within it. At molting the sac is thrown off with the old shell, and the new limb appears in its normal shape, but is smaller than the corresponding member of its pair. At subsequent moltings it increases in its relative proportions and eventually attains the normal size, unless the loss occurred only a molting or two preceding the acquisition of adult size. In that case the new appendage remains smaller than its fellow. Many adult crabs are found in which one claw is smaller than the other or both claws are below normal size. Such an undersized claw is termed by crabbers a "jew claw," i. e., reduced or "jewed down."

As an example of autotomy, the record of a crab which was kept under observation will be presented. A female crab, No. 9 of Table B, 1.687 inches in width and with the left claw missing, was placed in a small cage in the water on June 1. No papilla or limb bud had begun to form. This crab was kept under observation until July 21. The growth at the moltings which occurred during this time is recorded in the following table:

TABLE E.

Date of molting.	Width.	Length of claw, including entire arm.		Width of claw in widest place.	
		Right.	Left.	Right.	Left.
	Inches.	*Inches.*	*Inches.*	*Inch.*	*Inch.*
June 1 [a]	1.687	1.625	(b)	0.18	(b)
June 12	2.125	2.250	1.75	.25	0.18
June 26	2.750	2.930	1.87	.35	.31
July 21	3.750	3.500	3.50	.50	.43
Total gain [c]	2.063	1.875	3.50	.32	.43

[a] Placed in cage. [b] Claw missing. [c] Gain in 5 moltings or 51 days from time claw was lost.

It was necessary to close the experiment at this point. The left claw had practically reached the size of the right in three moltings, or in about 51 days from the time when it was lost. Plate LI, figure 24, represents the successive molts of the claws during the course of the experiment.

In the juvenile crab the completion of the process of regeneration never occurs except at the time of molting, although limb buds may be seen forming before this. The presence of a fairly large-sized limb bud is a sign that the crab is approaching or is already in the peeler state. If, as has been stated, molting does not occur after the crab has attained maturity and if regeneration does not occur except through molting, the adult crab can not renew cast-off appendages. Further research is necessary to clear up this point. Adult crabs cast off the appendages apparently as freely as do the juveniles. Whether they regenerate these or not, the author is not in a position to state. An adult female with limb buds has never been seen by the author or by crabbers who were questioned. Various adult females, as well as large males, which were kept under observation lacked certain appendages at the initiation of the experiments. During periods of from one to three months, throughout which the experiments were continued, the appendages were not renewed, no signs of limb buds formed, nor did any moltings occur. Quite large males, 6 or more inches in length, have sometimes been observed to bear limb buds. As males, however, are found which are at least 8 inches in width, it could not be said that the individuals with the newly forming appendages had yet reached the adult stage. Large males with discolored shells, barnacles, and similar apparent evidences of age, have not been observed to have appendages in the process of formation. It can not yet be stated definitely whether the adult crab has the power of regenerating appendages removed voluntarily or involuntarily.

MIGRATION IN CHESAPEAKE BAY.

The migrations of the crabs found in Chesapeake Bay are of sufficient interest to merit special discussion. Nearly all the sponge-bearing crabs are found in the southern part of the Bay, in fact, far enough south so that very few occur in Maryland waters. The chief spawning grounds are in the waters of the lower part of the Bay.

Records kept by a leading crabbing firm of Hampton, Va., for the summers of 1906–1913, inclusive, show that the average number of male crabs was 11.8 per cent of the catch handled by this firm during those seasons. During the summer of 1917 the author kept records of the percentages of male and female and sponge-bearing crabs found in certain lots taken at random from the catches brought in to the crab dealers at Hampton, Va. The results are summarized in the following table:

TABLE F.

Date.	Males in catch.	Sponge-bearing crabs in entire catch.[a]	Date.	Males in catch.	Sponge-bearing crabs in entire catch.[a]
	Per cent.	*Per cent.*		*Per cent.*	*Per cent.*
June 1	13	42	July 20	10	54
June 2	5	79	August 7	18	24
July 9	37	46	August 10	8	56
July 10	16	65	August 14	13	42
July 19	19	20	August 30	24	5.7

[a] From the early part of June until about the 20th, the sponge-bearing crabs comprised at least 75 per cent of the entire catch.

The average percentage of males will be seen from this table to be 16, a somewhat larger proportion than that indicated by the records of the firm at Hampton, Va. From all that could be learned from observations made at various points along the Bay, it is safe to say that at least 80 per cent of the hard crabs caught in the lower part of the Bay are females, while in regions around Crisfield, Md., an equally large percentage are males. From these data it would be predicated that relatively few sponge-bearing crabs would be found in Maryland waters. Observation substantiated this assumption. The number of sponge-bearing crabs occurring in Maryland waters is relatively quite small. In the fall months some few are found about Crisfield and to the southward in Pocomoke Sound, but in general the number is insignificant.

Practically all the young, then, are hatched in the southern part of the Bay. Sponge-bearing crabs begin to be fairly numerous during the last week of May. As seen in Table F, they are most numerous during the first two or three weeks of June. About June 15 to 20 the eggs begin to hatch. The bulk of the young are hatched from the middle of June to the middle of July. From then on a gradually decreasing number are hatched until about the first of September, after which time very few sponge-bearing crabs are found.

The young at some time between hatching and reaching maturity migrate northward to such a distance that the majority of them are found from about the latitude of the Rappahannock River, Va., to Baltimore, Md. They are most numerous in Tangier and Pocomoke Sounds and the neighboring waters of the Eastern Shore of Chesapeake Bay, in Maryland. This is, no doubt, due to the fact that the bottoms underlying these waters are extensively covered with sea grass and afford a very favorable ground for the molting process.

The proof for the fact of the migration of the young lies in this point: Almost no sponge-bearing crabs occur in these northerly waters. Countless numbers of immature crabs do occur there and form the basis for an immense soft-crab industry, an industry which does not exist in the southern part of the Bay.

As the young are found in these northern regions in vast numbers, but do not hatch there, they must have been hatched elsewhere and migrated to this point. The migration must have been made from the lower part of the Bay, since practically all of the sponge-bearing crabs are found there.

At the opening of the season, from about April 15 to May 1, crabs measuring from 1 to 2 inches in width are quite abundant in the vicinity of Crisfield, Md. So numerous are they that it has been found advisable to legislate against the catching of crabs measuring less than 3 inches in breadth. It is not probable that all these small crabs make the entire journey from the southern part of the Bay in the spring, but no doubt they have moved at least a part of the distance up the Bay during the preceding summer and autumn. It is not known what stage the young crabs are in either at the beginning or close of the migration. It may be that it is entirely completed during the first summer, possibly before the crab has finished the megalops stage. Or, on the other hand, it may not be undertaken until the crab stages are reached, and yet be completed before the close of the first autumn. However that may be, it is evident that the migration is made. Wherever cold weather overtakes them the crabs lie on the bottoms until spring, when they again resume their activities. Moltings occur at intervals in the course of this migration. The crabs cease the northerly migration at latest by the time the maturity and mating periods are reached. The fact that the sponge-bearing crabs are distributed over a region extending from the Capes to nearly the northern boundary of Virginia results in some of the young reaching more northerly points than others before attaining maturity. Observations carried out at various points on the Bay showed that the crabbing season opened later in the year the farther north the investigations were carried.

The young crabs then reach maturity and mate in the waters just mentioned, which extend from about the latitude of the northern part of Virginia to Baltimore, Md., and they are rather more numerous than elsewhere in the waters of Somerset and Dorchester Counties, Md. Pairs of mating crabs are found in great abundance in these regions from the middle of July to the last of August. Mating is described on page 115.

During the spring and summer of 1917, 3,898 crabs were examined either by means of the cast shells, the peelers in the floats, or the soft crabs in the packing rooms. It was found that in the early part of the season males predominated in numbers among the crabs handled for the soft-crab market, i. e., crabs which are immature or just about to reach maturity. As the season progressed, the relative number of females increased until in August there were more females than males among the crabs caught for the soft-crab trade. The following data for Crisfield, Md., constitute a typical illustration of the results obtained at various points on the Bay:

Date.	Males.	Females.	Total.
	Per cent.	*Per cent.*	*Per cent.*
May 22–25	78	22	100
June 21–23	58	42	100
July 23–27	42	58	100
August 23	38	62	100

The data here cited might at first thought lead to the belief that the males preceded the females in the migration and were found in greater numbers upon the bottoms. It seems to the author, however, that the explanation is simply that the males outstrip the females in growth and are the first to reach a marketable size. As the adult size of the male is greater than that of the female, in order to complete development in the course of a year, a more rapid growth must be maintained by the male than is required for the female. This would result in there being during the spring months more male crabs of marketable size than females upon the bottoms. As the females developed, the relative numbers of the sexes would tend to become more nearly equal. The preponderance of females caught during August is doubtless due in a small part to the partial depletion of the supply of males during the spring crabbing season. It arises mostly, however, from the fact that during August a great number of female peelers, while being carried by the males preparatory to mating, are caught on the trot-lines. These females, together with those taken by the scrape and the dip net, would make the total number of immature females caught greater than that of the immature males, which are taken only by the scrape and dip net. As peeler crabs do not eat much, they do not bite readily on the trot-line.

After maturing and mating in the waters of the central and upper parts of the Bay, the female crabs migrate southward during the autumn and lie on the bottoms of the southern part of the Bay during the winter. While the males move southward to some extent, they do not go as far as the females. Not a great many remain as far north as Maryland waters, although a few are taken in that region while dregding for oysters during the winter. This southerly migration is proved by the following facts:

First. Very few sponge-bearing crabs are found in Maryland waters; therefore, the females that have mated there must have gone elsewhere before the eggs were thrown out upon the abdomen.

Second. During the month of October and the early part of November of each year large schools of crabs are found by the crabbers in the southern part of the Bay; in fact, the average daily catch per crabber is often higher during this time than at any other part of the summer season. A leading crabbing firm of Hampton, Va., has kept an exact record of the daily catch of each crabber selling to it since its inception in 1878. This firm very kindly placed these records at the disposal of the author. From the data thus obtained the average daily catch per crabber for each week of the summer season was worked out for the years 1900 to 1902 and 1907 to 1917, all years inclusive. The results were plotted in the form of curves. That for the year 1917 is shown in text figure No. 1. It will be seen that the highest point of the curve is at the close of the season in November. Owing to the close season on sponge-bearing crabs during July and August, the curve for 1917 falls lower during those months than do the curves for similar periods in the years before the close season was established. The curve shown in text figure No. 2, for the year 1910 is typical of the condition obtaining in the southern

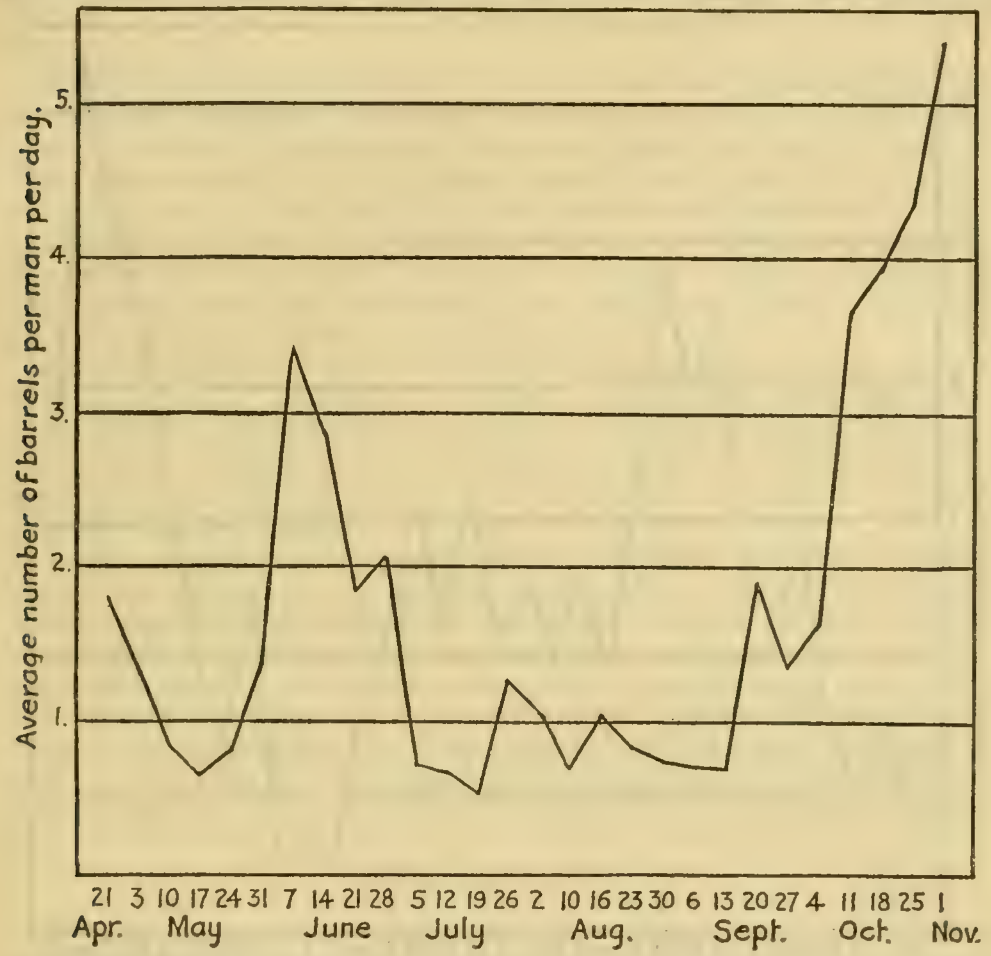

FIG. 1.—Curve showing average daily catch of crabs per crabber for each week during the summer season of 1917. The vertical line represents the number of barrels; the horizontal, the weeks.

part of the Bay before the establishing of this regulation. It shows that even before the institution of the close season there was a low period during the middle or last part of the summer. Nearly every curve for the 14 years which were analyzed exhibits the following characteristics: There are two high points, one occurring in the late spring, about May or June, and one in the fall, somewhere between the middle of September and the middle of November. In 7 of the 11 years for which complete records for the entire season were available the fall peak was higher than that for the spring. In 3 years of the 14 the records are not complete, owing to the fact that the firm was closed during the fall months and that no crabs were purchased. During August or the first part of September there is a depression, often very marked. These curves would indicate that crabs are most abundant in the late spring and in the fall, and that a slack season ensues in August or the early part of September. This is amply borne out by observation of the activities of the crabbers in that region. By the month of June the

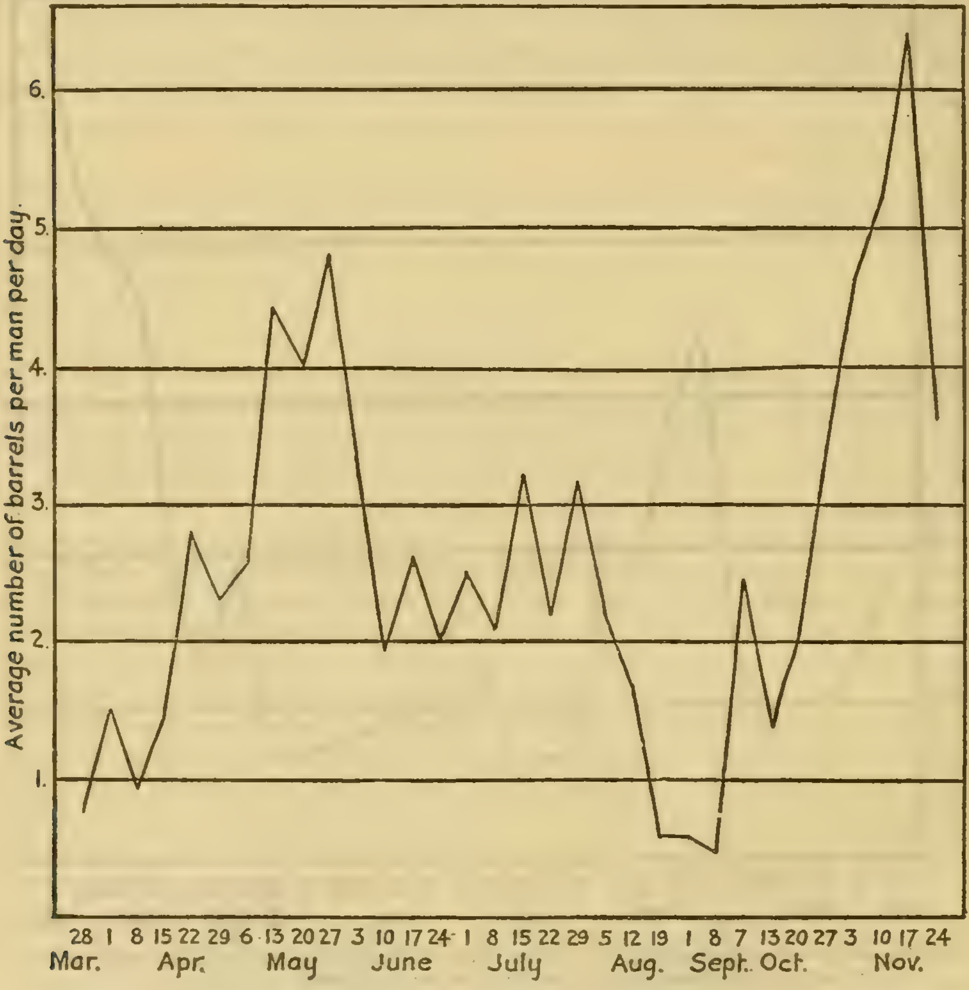

FIG. 2.—Curve showing average daily catch of crabs per crabber for each week during the summer season of 1910. The vertical line represents the number of barrels; the horizontal, the weeks.

crabs have become active and have left the deeper waters, being abundant in the shallower waters. The peak of the spring catch is attained then. The falling off in the abundance of crabs during August is probably due to two factors; first, a great number have been caught by the crabbers; second, many of the females which spawn in June and July do so for the last time and die shortly thereafter. This matter is discussed more fully on page 123. The sudden abundance of crabs appearing in October and November is due to the migration to these waters of the crabs which have matured and mated in more northerly waters. These constitute the school crabs previously mentioned. About 80 per cent of the individuals of these schools are females, and nearly all are adults.

Third. During the first part of the summer great numbers of sponge-bearing crabs are found in the southern part of the Bay. So we have these conditions: A great number of maturing females in Maryland which mate and go somewhere else, since no sponge-bearing crabs are found there, a sudden appearance of large schools of female crabs in the southern part of the Bay in October, crabs in considerable numbers on the bottoms in the southern part of the Bay during the winter, and an abundance of sponge-bearing crabs in the southern waters the following June. Every evidence points to the fact that the mature female crabs which mated in Maryland waters migrate to the southern part of the Bay and spawn there the following summer.

Records were kept of various catches made by the dredge boats at intervals during the winter of 1916–17. Fourteen lots dredged in the lower part of the Bay gave an average percentage of 85 females to 15 males. Four lots dredged from points north of the city of Cape Charles, Va., gave 55 females to 45 males. It is safe to say that at least 80 per cent of the adult crabs found on the bottoms in the lower part of the Bay during the winter are females.

In brief, the migrations of a majority of the crabs of Chesapeake Bay are as follows: They hatch in the southern part, move northward as they develop and molt, lie on the bottoms where winter overtakes them, resume their northerly course in the spring, continue molting, reach maturity in the waters of upper Virginia and central Maryland, and mate there. The females return south in the autumn, lie on the bottoms of the southern part of the Bay, and spawn the following summer, the males remaining mostly in more northerly waters. A certain number do not migrate, but spend their entire life in the lower part of the Bay. Some small crabs may be found there during the entire summer. The great majority, however, of the young migrate as described above.

GENERAL HABITS.

Hay [a] presents an excellent description of the general habits of the blue crab. Certain portions will be quoted as affording the most convenient method of presenting these interesting features of the natural history of the blue crab.

> Either in the water or on land the blue crab is an animal of great activity and has considerable power of endurance. Progression through the water is effected by means of a sculling motion of the broad, oar-like posterior legs, and under ordinary conditions is slow, the effort of the animal being apparently only to keep itself afloat while it is borne along by the current. Under these conditions the movement is either backward or sidewise. The shell is held with the posterior portion uppermost, the legs are brought together above the back and strike backward and downward at the rate of from

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[a] Hay, op. cit., pp. 401–403.

> 20 to 40 strokes per minute. When alarmed, however, the animal strikes out with great vigor and rapidity, moving its paddles too swiftly for the eye to follow; it moves through the water almost as rapidly as a fish and quickly sinks below the surface. When on the bottom and undisturbed, the crab may be seen to walk slowly about on the tips of the second, third, and fourth pairs of legs, the large pincers being held either extended or folded close under the shell and the paddles either raised and resting against the back of the shell or assisting the movement by slow sculling strokes. In such cases the movement is in any direction—forward, backward, or sidewise—although the usual direction is sidewise. If the animal becomes alarmed, it moves away by a combination of the walking and swimming motions and often disappears like a flash. * * * All the legs are in motion except the large first pair. Of the latter, the one on the side toward which the animal is moving is held straight out sidewise, while the other is folded up under the shell.
>
> The coloration of the crab is such as to harmonize very perfectly with the surroundings, and the animal attempts very little concealment if there are other objects on the bottom. Often, however, a clear, sandy bottom or some oozy pond will be found to be almost alive with crabs which have buried themselves until only their eyes and their antennæ are exposed.

The experience of the present author has been that it is only immature crabs which bury in this manner. No adults were found so hidden.

> In thus hiding, the crab goes nearly vertically backward into the bottom and then, by a few movements, turns slightly, so that the shell rests at an angle of about 45 degrees. The material above settles down and effaces all traces of the entrance. It usually happens that the bottom affected by the crab is firm enough to render this operation somewhat slow and it rarely attempts to escape pursuit in such a way. It seems probable that concealment is usually adopted as an ambush from which a sudden attack can be made on some passing fish.

The author has often seen immature crabs dart away and burrow in the substratum, as described above, apparently in order to escape pursuit. It is probable that burrowing may be undertaken either for the purpose of escape or for lying in ambush. Hay describes an interesting habit of the crab which the author has never had the opportunity of witnessing:

> In certain places, notably shallow ponds and streams which become nearly dry at low tide, the crab may be observed to dig rather large, conical holes, apparently as reservoirs, and to take up its position in the deepest part * * * and waits until the rising tide offers an opportunity to move about again.

The hole is described as about 1 foot across and 6 inches deep. The sand or mud is loosened by means of the tips of the walking legs and carried, clasped between the claw and the underside of the body, to the side of the excavation.

> The color of the crab is more or less variable, and it is believed by the fishermen that the animal is able to change its hue slightly to approximate the color of its surroundings. Light grayish-green individuals are said to be taken on sandy bottoms, while the dark olive-green are said to be found among the grass. This theory, however, is not very well borne out by crabs held in captivity in the live boxes, for there they retain their original colors, and even after they have cast their shells exhibit quite as much variety as before.

The author agrees with the last statement of Hay and is of the opinion that there is no approximation of the color of the bottom by the crabs. In a catch, all the individuals of which were taken from the same area, he has seen specimens exhibiting all the varieties of colors which are found in crabs.

> The blue crab's food is of a varied character, but the animal is preeminently a scavenger and a cannibal. In the shallow waters of ponds and small tidal streams it preys to a certain extent upon small fish, which it stalks with some cunning and seizes by a quick movement of its large claws. In such situations, too, I have sometimes observed it nibbling at the tender shoots of eel grass or other aquatic vegetation, or picking at the decayed wood of some sunken log. Its favorite food, however, is the flesh of some dead and putrid animal, * * * stale meat or a rotten fish.

An injured crab, if thrown into the water, will be speedily set upon by its associates and torn to pieces. Even one that is uninjured, if small or in the soft-shelled condition, is likely to be captured and eaten by stronger individuals.

In eating a bit of food the crab first grasps it in the large claws and pushes it back under the front of the shell, where it is seized between the tips of the second pair of legs and pushed forward and upward to a point where it can pass between the third maxillipeds to the jaws. These strong organs masticate the food, while the other mouth parts prevent the escape of the smaller particles. It is then swallowed and the complicated set of teeth in the stomach reduce it to a thin fluid mass before it is allowed to pass into the intestine.

REPRODUCTION.

MATING.

Among the crabs of Chesapeake Bay, mating occurs chiefly in Maryland waters and lasts from about the middle of July to the last of August, although mating crabs are seen earlier than this in the lower part of the Bay. The crab reproduces by means of eggs which are laid by the female and carried on the abdomen until hatched, as described on page 97. Previous to being laid the eggs are fertilized by spermatozoa which have been implanted in the body of the female crab by the male at the time of copulation. Mating and copulation occur, as far as is known, once only in the lifetime of the female crab. This takes place when she is yet soft at the time of the last molting, when the triangular-shaped abdomen changes to the rounded form. For a few days previous to copulation the female is carried about by the male, which clasps her, back uppermost, against the lower side of his body by means of his three pairs of walking legs. This leaves his claws and swimming legs free and he is enabled to feed or swim about. He at times frees a number of walking legs and moves over the bottom. Such pairs of mating crabs are called "doublers" and are often seen clinging to posts or pilings in the water. As already noted, the male's hold upon the female is quite tenacious, and both individuals are caught in great numbers on the trot-line, due to the male seizing the bait and both being drawn to the surface.

In all the numbers of pairs which have been observed by the author and by crabbers who were questioned, no male crab has ever been found, in nature, carrying any sort of female except one with a triangularly shaped abdomen and which bore all the marks of a peeler, or, more rarely, a soft-shelled female with a broad abdomen. If a female of the former sort is removed from the male and kept in a float, molting occurs, and the broad abdomen is acquired. Dissection shows that in such a case copulation has not yet occurred. If the male be carrying a soft-shelled female, it will be found that copulation is in progress or has just been accomplished.

Copulation.—If the female in the peeler state is left with the male, however, copulation ensues as soon as she has molted and while yet soft. The author observed one pair of copulating crabs which were found in a float. The female was lying on her back on the bottom of the float, with the abdomen extended backward, thus exposing the openings of the oviducts (Pl. XLIX, fig. 16). The male stood above her, with the walking legs partially clasped about her body and with the two intromittent organs (Pl. XLIX, figs. 14 and 15,) inserted in the openings of her oviducts. Opportunity was not given for observing the beginning or concluding stages of the copulatory act.

Hay [a] states that the male frees the female as she actually begins to molt, stands near by during the process, and seizes her again at its completion. A reliable crabber, who stated that he had several times observed the process of copulation in the blue crab, told the author that the female crab voluntarily turns upon her back and spreads open the abdomen to expose the genital pores. Copulation lasts for a day or two, the female being carried about by the male, as before molting, except with the under side of her body uppermost. After copulation the female resumes her normal position and is usually carried by the male until her shell is hardened.

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[a] Hay, op. cit., p. 405.

Male reproductive organs.—Plate XLIX, figure 14, shows a view of the male crab with the abdomen turned back to display the intromittent or copulatory organs. It will be seen that there are no appendages of moment other than these upon the abdomen. They correspond to the two anterior pairs of swimmerets upon the abdomen of the female and have been modified in the course of development to form copulatory organs. From Plate XLIX, figure 15, and Plate XLVIII, figure 2, it will be apparent that each organ consists of two parts, the one in front having a fairly broad base and being extended forward into a long, fine, slightly curved portion. The one in the rear is attached to the succeeding segment of the abdomen, is short, and has a sort of spur which fits into an opening in the base of the large anterior part of the organ. It evidently acts as a brace to strengthen the entire organ.

Plate XLVIII, figure 11, represents a dissection of a male crab, showing the testes, which lie upon the digestive glands or "fat;" the glands, which secrete a pink-colored, jellylike fluid for carrying the spermatozoa; and the long, thin, white, convoluted tube, or vas deferens, through which the spermatozoa pass to the copulatory organs. Each of these tubes (Pl. XLIX, fig. 15, and Pl. XLVIII, fig. 2), passes out through an opening on one of the segments, the coxopodite, of the swimming legs and into the base of the large part of the copulatory organ. The spermatozoa pass through a hollow in the center of these organs and into the sperm sacs of the female.

Female reproductive organs.—Plate XLIX, figure 16, shows the under side of an adult female crab. The broad abdomen is turned back, exposing the openings of the two oviducts and the large swimmerets, which are borne on the lower side of the abdomen. The copulatory organs of the male are inserted into the two openings during copulation. The eggs pass out through these openings when laid and become attached to the inner portion of each pair of swimmerets, thus forming the sponge (Pl. L, fig. 19, and Pl. LI, fig. 22).

Plate XLVIII, figure 3, represents the dissection of a female crab in the stage immediately preceding molting for the last time. The ovaries are very narrow and are white in color. After this molting and before copulation, the ovaries are very little larger, and the sperm receptacles are flat, empty sacs with a fairly tough, white wall. The ovaries are attached to the upper side of the sperm sacs, and at the point of attachment there is a passage leading from each ovary into the interior of the sperm sac. A tube or oviduct leads from each sperm sac and opens on the exterior, as shown in Plate XLIX, figure 16. At the time of copulation the pink, jellylike fluid carrying the spermatozoa is forced into the sperm sacs, which, as a consequence, become hard and distended and of a pink color (Pl. XLVIII, fig. 4, and Pl. L, fig. 17). The presence of sperm sacs of such a nature is always a sure indication that the female has mated within the preceding few days.

Within a few weeks the pink jelly will be found to have disappeared, leaving the sacs flat again, but with a white ridge along their lower side (Pl. XLVIII, fig. 6). The spermatozoa will be found stored in this ridge. They are carried from the male by the jelly in bundles of an oval shape slightly larger than the eggs of the female. Such bundles are called spermatophores, and one is shown in Plate XLVIII, figure 8. The spermatophores disintegrate as the jelly disappears from the sperm sacs and the spermatozoa are found to lie in a mass in the white ridge at the bottom of the sperm sacs. Drawings of the spermatozoa which have been mounted for microscopic study are shown in Plate XLVIII, figure 9.

Development of the ovaries.—The ovaries enlarge until they are about one-half inch in width (Pl. XLVIII, fig. 13), at the same time becoming a bright orange-red color. The color is due to yolk granules in the eggs, as described earlier. If examined microscopically, some of the eggs will be found to have reached the size at which they are when laid upon the abdomen (Pl. XLVIII, fig. 1). Smaller eggs, which will be laid in subsequent batches, will also be found.

The enlarging of the ovaries is not dependent, however, upon copulation. It has been found that they enlarge and the eggs likewise increase in size, even if copulation has not occurred. On June 19 a female crab with the triangularly shaped abdomen was placed in a float with no male present. On June 25 it molted, the abdomen changing to the rounded form. On July 21 this crab was killed and its ovaries examined. They were found to have attained, during this period of only 26 days, to about one-half the full width. The eggs were about one-half the mature size. The color was orange. The sperm sacs were thin and flat, as already described for the crab which was removed from the male immediately before copulation. There was no white ridge found along the lower side, such as is present in a crab which has copulated. It is possible that such a crab would lay the eggs when they had attained the full size, but they would, of course, be infertile, and therefore would not hatch.

It is thought by many crabbers that the abdomen of the female will not change to the broad form unless the male is carrying the female at the time of the last molting. This is shown to be an erroneous idea, both by the evidence of the experiment just cited and by the fact that at least four other female crabs were allowed to undergo the last molting while under observation, no male being present, and in each case the normal, broad abdomen appeared.

Probably very few female crabs, however, pass the last molting stage in nature without mating. Observations made at various times on at least 300 adult females revealed none which had failed to undergo copulation.

Fertilization.—The eggs are, in all probability, fertilized as they pass through the sperm sacs on the way from the ovaries to the exterior at the time of spawning. The spermatozoa are found in the sperm sacs, as before stated. The author was able to find no evidence that would lead to the belief that spermatozoa pass up into the ovaries and meet the eggs there. Eggs taken in May from the hollow in the middle of the fully developed ovary gave no appearance of having been fertilized and did not develop when kept in sea water. On the contrary, they always become swollen within the course of 10 or 15 minutes (Pl. XLVIII, fig. 12), apparently from having absorbed water. Eggs taken from the sponge of the female were found to be covered by a tough transparent membrane, which is probably a means of protecting them from the action of the sea water, by which they are surrounded. It seems probable that the eggs lack this tough membrane until after they have passed through the sperm sacs and have been penetrated and fertilized by the spermatozoa which are found there.

Interval between copulation and spawning.—The length of time which elapses between copulation and the laying of the eggs depends on the season at which copulation occurs. Experiments which were performed in the endeavor to throw some light on this question follow.

On various dates between June 18 and 26, 15 adult female crabs were selected and confined in floats for observation. By the external appearance it had been ascertained that these crabs had molted for the last time within the previous few days. Such crabs can readily be distinguished after a little practice by their fresh, blue color, the weakness of the muscles holding the abdomen against the lower side of the body, and the bright, clean, slightly golden appearance of the swimmerets. At the same time several such females taken from the same catch were dissected and found to have copulated. It was assumed that those selected for the experiment had also copulated. During the course of the experiment the crabs were fed with fresh fish. On August 1 one female threw out a very few eggs. About August 15 two others each formed a sponge, the eggs of which hatched from the 27th to the 30th. In general, it was found in all experiments with female crabs confined in floats and crates that only a small percentage of such individuals spawned. The confinement was apparently prejudicial to the full exercise of their natural functions. In the case of the three individuals which did spawn it will be seen that the interval between copulation and spawning was about two months.

Further, on June 20, a female crab with the triangularly shaped abdomen was confined in a float with a male. On June 25 it was found that the female had molted and had the broad abdomen. Presumably she had mated, although the act had not been observed. The male was removed. On August 27 it was found that the female had thrown out a small sponge within the preceding two or three days. Upon microscopic examination the eggs were seen to have begun development, showing that mating had occurred and that they had been fertilized. In this case also about two months elapsed between copulation and spawning.

The facts just mentioned apply, however, to the fairly small percentage of female crabs which mature in June or the early part of July, and more especially to those of the southern part of Chesapeake Bay, since not many mature before the middle of July at points farther north in the Bay. Earlier in this paper it was shown that the most of the mating occurred from the middle of July to the last of August and that the female crabs migrated to the southern part of the Bay and spent the winter on the bottoms thereof. Later it is proved, page 119, that these crabs spawn the following June and July, thus accounting for the abundance of sponge-bearing crabs found in the late spring and summer in the southern part of the Bay. In this case the period elapsing between copulation and spawning is about 9 or 10 months. During the winter the crab is inactive, eating very little or nothing. Its natural functions are therefore practically suspended, for it remains in a state of semihibernation.

SPAWNING EXPERIMENTS WITH CRABS TAKEN DURING THE WINTER.

The fact that the female crabs mate during one summer and do not spawn until the next, as stated in the preceding paragraph, is proved by the following examinations and experiments: During the winter of 1916–17, 238 adult female crabs taken from the catches made by various dredge boats were examined. In each case specific records were kept of the condition of the ovaries, sperm sacs, eggs, etc. In 204 of these, the ovaries were found to be large and full, as shown in Plate XLVIII, figure 13, and Plate L, figure 18. In 30 cases the ovaries were small, but microscopic examination revealed the presence of small eggs within them. Four crabs taken early in the season had recently copulated, as was shown by the presence in the sperm sacs of the pink, jellylike fluid (Pl. L, fig. 17). The sperm sacs of the other 234 crabs had the small white ridge along the lower side (Pl. XLVIII, fig. 6). Spermatozoa were found within the mass which made up this ridge. Plate XLVIII, figure 9*B*, shows some of such spermatozoa after having been mounted for study. Every appearance was given that these crabs had mated during the preceding summer and would survive the winter and spawn the following summer.

To test this matter more fully, the following experiments were performed: Twenty-eight adult female crabs which had been taken on March 28 with the dredge were placed in a crate made of chicken wire fencing and measuring 2 by 2 by 4 feet. This crate was placed in water of such a depth that it was entirely covered at low tide. The crabs were fed nearly every day with pieces of fresh fish. On June 28, 8 crabs were living, one of which bore a sponge of normal size. On March 22, 19 crabs which had been taken with a dredge were confined in floats in the water of the Bay. These crabs were fed with fish. On June 15 one spawned, and on June 22 another spawned. The latter was kept under observation, and upon microscopic examination on June 25 the eggs showed marked cleavage, proving that they had been fertilized and were developing.

Through the courtesy of John S. Parsons, late commissioner of fisheries of Virginia, the author was enabled to utilize a small cove at Lynnhaven Bay, Va., in which to keep crabs under observation. Wire netting was placed across the mouth of the cove in such a way that the crabs were prevented from escaping, while allowing direct connection between the water of the cove and that of the Bay. The cove was divided by a close, wooden partition, so that two independent experiments could be maintained simultaneously.

On April 18 the author accompanied a dredge boat which secured 2½ barrels of crabs in Lynnhaven Roads, east of Norfolk, Va. On the same day these were put in one part of the cove by the author and Messrs. Owens and Woodhouse, crab inspectors of the the State of Virginia. During the first week in June several dozen crabs bearing sponges were removed from the cove by Mr. Woodhouse and sent to Commissioner Parsons. On June 7 the author and Mr. Woodhouse removed from the Cove six sponge-bearing crabs. Two of these are shown in Plate LI, figure 22, being the two at the right of the picture. Quite a number of others were seen in the water of the cove. Apparently they spawned there about as freely as in their natural habitat.

From the evidence of these examinations and experiments it is plain that the connecting link is perfect between the crabs that mate one summer and those that spawn the summer following. The great bulk of the crabs of Chesapeake Bay, after mating in Maryland waters where they matured, move to the lower part of the Bay, retain their eggs during the winter, and spawn the following June and July.

NUMBER OF BATCHES OF EGGS LAID.

The prevailing supposition among most crabbers is that the female crab lays but one batch of eggs and dies shortly thereafter. Binford,[a] however, in 1911, reported that he observed the eggs hatch from a sponge on a female crab, which he then dissected. The ovaries were examined and found to contain "nearly mature eggs, as was judged from their size and color." He concluded from this fact that the crab would have been capable of spawning again. Hay and Shore,[b] 1918, state that it is believed that the female crab molts but once, "although she may produce more than one lot of eggs." The following experiments and observations were made in an endeavor to test this matter more fully.

Two crates, measuring 2 by 2 by 4 feet, were constructed from chicken wire fencing. About 30 female crabs, which were known to have spawned, were confined in each crate during September, 1916 (Pl. LIV, fig. 36). The crates were partially sunk in the mud and water to a depth of about 6 feet at low tide. The crabs were fed two or three times a week with bits of fish which were pushed by a stiff wire down a galvanized-iron sheeting tube into the crates. Feeding was discontinued about December 1, as it was found from other experiments that the temperature of the water was below 50° F. and that crabs eat little or nothing at such low temperatures. It was hoped that some of the crabs might survive until the following spring, when the question of spawning could be tested. The effort was a failure, however, for it was found on lifting the crates in the spring that the crabs were all dead.

Effort was also made to keep some adult female crabs through the winter in the United States Fisheries biological laboratory at Beaufort, N. C. Although two crabs survived until the following June, and were placed in floats, neither spawned. Judging from their appearance at the time when placed in the floats, they were not in a very vigorous or healthy condition.

During the winter of 1916–17 a method was found by which this problem was successfully met and it was shown that at least a second batch of eggs may be laid by the female crab. The procedure followed and the results attained are here discussed.

It was found that it was possible to determine, in the case of many of the female crabs which were examined during that winter and the subsequent spring, whether they had ever produced a sponge. Microscopic examination of the hairs on the swimmerets of these females revealed, in many cases, occasional hairs which still bore the tendrils that had served to hold the eggs of a sponge produced at some previous time, most probably the season immediately preceding. Often, the fragments of the shells which had incased the eggs were yet attached to the tendrils. Plate XLVIII, figure 10, represents a hair from the swimmerets of such a crab. Numerous tendrils and shells are to be seen still adhering to it.

The method of examination was as follows: A cursory examination with the unaided eye or a hand lens was first made. After some experience had been gained, it was found that remnants of a sponge were not found in case the swimmerets were bright and clean in appearance. In case they were blackened or débris of any sort was apparent, a small portion of the tips of the hairs on the anterior swimmerets was clipped off with the scissors and examined with the dissecting misroscope. It was found that very little or no bleeding resulted and that the crab very seldom, if ever, died as a result of the removal of the tips of the hairs in this manner. Such individuals could, therefore, be kept under observation to await subsequent spawnings.

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[a] Binford, op. cit., p. 1.

[b] Hay, W. P. and Shore, C. A.: The Decapod Crustaceans of Beaufort, N. C., and the Surrounding Region. Bulletin, U. S. Bureau of Fisheries for 1915–16, Vol. XXXV, p. 433. Washington, 1918.

The presence of such remnants of a sponge upon the swimmerets of a female crab is conclusive proof that she has at one time laid a batch of eggs, presumably during the summer immediately preceding. The absence of any such remnants is not proof that the individual in question has never spawned, since all the hairs may have become entirely cleared of any portions of the sponge. It was seldom found that many hairs bore remnants; in many cases they would be found upon only one or two located at the tips of the anterior swimmerets.

During the winter and spring, in almost any barrel of crabs which was examined, it was possible to find without difficulty females bearing such remnants of a sponge. On April 18 the author accompanied a dredge boat which was working in Lynnhaven Roads, Va. Three barrels of crabs were dredged in about five hours' time. During this time, with the aid of a dissecting microscope, one-half barrel of crabs which bore remnants of sponges was selected from those dredged. This means that at least 16⅔ per cent of those dredged up on this occasion had spawned during the preceding summer. As not nearly all those obtained were examined, owing to lack of time, the actual proportion bearing remnants was no doubt greater than this. Most of those which bore remnants appeared to be vigorous and capable of living the remaining weeks until June.

On May 15 seven females were removed from a barrel of crabs that had been caught by the trot-line. All were living. Upon examination it was found that three had spawned during the preceding summer. Crabs bearing remnants of an old sponge usually have a peculiar rusty-brown color which is not possessed by the other females. This is probably due to the fact that the former are older and have usually survived two winters. In searching for remnant-bearing crabs this color characteristic proved to be a useful guide. The proportion of three to four, apparently, as just shown, would not hold for the entire barrel, since the seven crabs were not selected at random, but with reference to the brown color.

As late as June 1 it was possible to find individuals bearing remnants of the sponge of a previous season. Thus it is plain that the crabs which have spawned during one summer may survive throughout the winter until the following spawning season.

Crabs which carried remnants of a sponge were dissected during the winter and spring of 1916–17. This examination led to the belief that such crabs were capable of spawning the ensuing summer. The ovaries were large and full; in fact, they appeared in every way similar to those of the individuals which had mated the previous summer and had not yet laid any eggs. (Compare Pl. XLVIII, fig. 13, and Pl. L, fig. 18.) The sperm sacs were found to contain the white ridge or mass (Pl. XLVIII, fig. 6), in which spermatozoa (Pl. XLVIII, fig. 9*B*), were found, as in the case of the other crabs. Apparently enough spermatozoa were provided by the male at the time of the one copulation which the female underwent to fertilize successive batches of eggs. What was not utilized at the passage of the first lot of eggs through the sperm sacs remained there in a living condition and would fertilize later lots. Such a phenomenon is known to be true for the stone crab of our Atlantic coast,[a] and probably for the edible crab of England.[b]

Crabs bearing remnants of a sponge which had been produced during a preceding summer were selected during the spring of 1917 and kept under observation until June in order to ascertain whether or not they would spawn again. The half a barrel of such crabs which was selected on April 18, as already stated, was placed the same day in one part of the cove at Lynnhaven Bay, at the time of the initiation of the experiment with the other dredged crabs, previously described. During the first week of June several sponge-bearing crabs were removed from this part of the cove by the crab inspector, Mr. Woodhouse, and sent to Commissioner Parsons. On June 7 the author and Mr. Woodhouse removed one sponge-bearing crab from this part of the cove. This individual is shown in Plate LI, figure 22, being the one on the lower left.

On March 22, 19 crabs which bore remnants of a sponge were selected from a lot that had been caught with the dredge. These were confined in floats and fed with fish during the course of the experiment. On June 4 two spawned and on June 15 another. On June 22 a fourth spawned. The last was kept under observation, and on June 25 the eggs were examined and found to show marked cleavage, proving that they had been fertilized and were developing. The individual which spawned on June 15 was also kept under observation. On June 29 it was found that part of the eggs had hatched. By July 2 nearly all the young had hatched and left the mother. The crab was killed and dissected. The ovaries were found to contain eggs of about one-third full size. Indications were thus given that still another lot of eggs would be laid.

On April 24 a female crab bearing remnants of a sponge was placed under observation. On May 30 this individual spawned. This crab is shown in Plate L, figure 19.

On June 1, in a lot brought in by a trot-line boat, a female crab was found which bore remnants of an old sponge and also some eggs, which were recognized by their color and appearance to have just been laid. Many full-sized eggs were found in the ovaries. This individual had evidently been caught shortly after having begun to throw out what was at least the second lot of eggs. The spawning process was thus interrupted before completion.

Further experimentation showed that some of the female crabs lay two batches of eggs during the same summer. After about June 20 it was observed that the eggs of the majority of the sponge-bearing crabs were beginning to hatch. By July 1 probably half the young for the season had been hatched. (See table F.) It was thought possible that some of the females which had thrown off a sponge in June would produce another lot of eggs that same summer.

On June 27 a dozen such females were confined in a float. On July 6 one was found to have spawned during the preceding 24 hours. Upon examination the eggs were found to show faint cleavage lines, indicating that they had been fertilized and were beginning to develop. This also shows that cleavage had probably not begun until the eggs had been deposited upon the abdomen, otherwise it would have reached a more advanced stage. On July 9 another crab threw out a few eggs and on July 28 another spawned. In another similar experiment, two crabs were found to spawn.

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[a] Binford, R.: The Germ-Cells and the Process of Fertilization in the Crab, *Menippe mercenaria*. Journal of Morphology, vol. 24. June, 1913, p. 161. Philadelphia.

[b] Pearson, J.: Cancer (the Edible Crab). Trans., Liverpool Biological Society,, Vol. XXII, 1908, p. 468. Liverpool.

These experiments show that the female crabs spawn twice or more times during the course of their lives. The successive lots of eggs are fertile and will hatch. Enough spermatozoa are stored in the sperm sacs of the female at the time of the one copulation which she undergoes to fertilize all the eggs which she lays.

It is evident, also, that the adult female crabs found on the bottoms in the southern part of Chesapeake Bay during the winter are not spawned-out or barren crabs. On the contrary, part of them are individuals which have mated the previous summer and will lay their first lot of eggs the next season, and part are crabs which have produced one or more sponges the preceding summer and will survive the winter and lay again the succeeding season. Most of the females lay one or sometimes two lots of eggs the first season, one toward the early part and the other (when this occurs) later on, survive the winter, and lay again the next season. Some lay the first lot late in the summer and one or two batches the succeeding season.

Of course a crab will not spawn indefinitely and just as surely it must finally die. The ovaries of some of the crabs which spawned in captivity were found to contain no more eggs, however small. Evidently such crabs had spawned out and would produce no more sponges. Crabs whose ovaries are in this exhausted condition are found during the summer among those taken for market. As the ovaries of none of the 238 individuals examined during the winter were in this condition, it seems probable that the female crab dies shortly after having produced her last lot of eggs. This probably occurs during the late summer or early fall. As mentioned earlier, this is, no doubt, one of the causes for the falling off in the available supply of crabs in the southern part of Chesapeake Bay during August of each year. This decrease is manifested in the curves of the averages of the daily catches of the 14 years for which the data were worked out. A typical curve is shown in text figure No. 2.

WINTER HABITS.

It has usually been thought that during the winter the crabs retire to fairly deep water and bury in the mud or sand. It is very apparent that this view is in part correct. Most of the crabs proceed to the deeper water to pass the winter. The author is reasonably sure, however, that the majority of the crabs do not bury in the substratum. This, at least, is true of those found in the waters where dredging is carried on. The author has been told of cases in which crabs were found buried during the winter in the mud of a shallow cove or creek, but has never had the opportunity of verifying such statements by personal observations.

If one judges from the appearance of the hauls made while dredging, the crabs brought up have not been buried. This is especially true in cases where the dredging was being carried on over fairly hard, sandy bottoms. Many observations were made when the teeth of the dredges were so clogged with seaweed that they could not possibly be sinking into the comparatively hard sand, even if it is supposed that the crabs could have buried in it. Crabs were being brought up in average quantities. Many dredgers have given instances in which buoys were left to mark an area on which crabs were abundant, and on the next day it was found that the crabs had moved away. Other instances have been given in which dredgers systematically followed a school of crabs from one point to another. These facts show that the crabs may move about to a considerable extent during the winter months.

From observations which were made on crabs being kept in floats, it was found that, as the temperature lowered, the crabs became more and more sluggish and at about 50° F. moved very little and practically ceased to eat. On warmer days they became more active. Crabs were also kept in wire crates partly sunk in the mud. At various times during the winter examination was made and it was found that the crabs had not buried in the mud.

It seems most probable that the crabs, instead of burying, merely move toward deeper, and consequently warmer, water as winter approaches and as the temperature falls become more and more inactive and finally lie motionless on the bottom. On milder days they move about to some extent, especially if disturbed.

LENGTH OF LIFE.

The only original statement concerning the length of life of the blue crab which is found in the literature is that of a correspondent quoted by Dr. Mary J. Rathbun.[a] The probable duration of the life of both the male and the female is there estimated to be seven years. The correspondent bases his conclusion partly on certain wholly casual observations made during his boyhood and partly upon assumption. The period before the crab attains maturity is stated to be three years, and it is thought to molt twice each year during this time. As the correspondent is dealing with the blue crab found near Victoria, Tex., it is possible that the life history of that form is widely different from that of the crab of the Chesapeake Bay, although both belong to the same species. On the whole, however, it does not seem that a great deal of weight can be attached to the opinions set forth on this subject by the correspondent.

In connection with the blue crab of the Atlantic coast, and of Chesapeake Bay, in particular, experiments and observations led to a very different conclusion from that arrived at by the person mentioned by Dr. Rathbun. It was found that a crab which is hatched during one summer will reach maturity the next, molting from 15 to 20 times during this interval. It then mates and, in the case of the female, spawns at the age of 2 years, during the summer following the one in which mating occurs. The female was also found to be able to survive the winter following the first spawning and to spawn again at the age of 3 years. It is probable that this is the usual length of life of the female, although some may survive until yet another season. In the case of the male, there are no spawning periods by which to judge its term of life. The best evidence available shows that the males mature in one year, as do the females. During the spring and early summer full-sized males are found which, judging from their brownish color and the presence of barnacles, etc., upon their shells, have survived at least one winter after reaching maturity. It is very probable that the usual term of life of both the male and female crab is 3 years.

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[a] Rathbun, op. cit., p. 370.

SUMMARY.

The following is a list of the main points brought out in this report:

1. The blue crab, *Callinectes sapidus*, is found in the salt and brackish waters of the Atlantic coast from Massachusetts to South America.

2. The young hatch from eggs borne for about 15 days upon the swimmerets of the abdomen of the female in a mass called a sponge. There are about 1,750,000 eggs in one sponge.

3. The young do not cling to the swimmerets of the mother after hatching. They do not devour the mother as they are hatched, as supposed by some.

4. The young, after hatching, increase in size only when they molt. They pass through two stages before reaching the true crab shape. In the first, or zoëa stage, molting occurs four or five times; in the second, or megalops stage, probably only once. About one month is required to complete these two stages.

5. In passing from the megalops stage to that of the adult-crab stage about 15 moltings occur. The average time between molts is 15 days, ranging from 6 days for the early stages to about 25 for the last. The average increase in width at each molt is one-third.

6. The crabs mature and mate during the second summer, at the age of 12 to 14 months.

7. The female reaches a molting at which the abdomen changes from a triangular to a broad, rounded form. This is most probably the last molting. The male, also, probably does not molt after reaching maturity.

8. Molting is described. The crabs become hard again within two or three days after molting. Neither the tides nor the moon have any effect upon the molting process, although the tides do affect the distribution of the crabs.

9. Juvenile crabs possess the power of regenerating an appendage which has been lost or voluntarily thrown off. Regeneration is completed at molting, but it is not yet known whether it occurs in the adult crab, which most probably does not molt.

10. The young of the crabs of Chesapeake Bay hatch in the lower part of the Bay during June and July, migrate northward, mature in Maryland waters the next summer, mate there during July and August, then the females move southward in the fall, and pass the winter on the bottoms in the southern part of the Bay. They spawn the following spring and summer. The males remain for the most part in more northerly waters.

11. Mating occurs in the female at the time of the last molting, while she is yet soft. She is carried by the male for a few days prior to such molting, after which copulation is effected. At this time sufficient spermatozoa are implanted in the sperm sacs of the female to fertilize all the eggs which she lays during her lifetime. Fertilization is effected in the sperm sacs of the female. The ovaries of the female are very small at the time of the last molting, but begin to develop then, whether or not copulation occurs. If mating occurs quite early in the season, the eggs are laid within about two months. In the great majority of cases, however, mating occurs in July or August and the eggs are not laid until the following spring or summer.

12. Practically all the female crabs found on the bottom of the southern part of the Bay are filled with eggs and will spawn the following season. This was amply

proved by keeping some of such crabs until spawning season and finding that spawning ensued.

13. A female crab may lay two and probably more batches of eggs during the course of her life, the spermatozoa from the one copulation sufficing to fertilize successive lots of eggs. This was proved both by microscopic examination and by experimentation upon crabs which were known to have laid at least one previous batch of eggs. The female crab dies shortly after having laid the last lot of eggs. Death usually occurs in the late summer or autumn.

14. The general habits are discussed, including walking, swimming, methods of concealment, feeding, etc. The majority of the crabs do not bury in the substratum during the winter but lie on the bottom in the deeper water in a more or less dormant state.

15. The usual term of life of the crabs is probably about three years.

EXPLANATION OF PLATES.

PLATE XLVII (Frontispiece).

(Drawn by Mrs. W. P. Hay.)

Above.—Female crab immediately after having molted and acquired the broad abdomen. The coloring of the crab is most marked while the individual is yet soft.

Below.—At the left (upper) two outer segments of swimming leg of immature peeler crab, showing the pink line which is the "sign" most commonly used to distinguish peeler crabs; (below) portions of arm of claw showing distinctive markings of the peeler; at the right, abdomen of immature female crab in peeler stage showing the reddish hue assumed at that stage.

PLATE XLVIII.

Fig. 1. Mature egg taken from ovary of blue crab. Stained to show nucleus. *A*, nucleus; *B*, yolk cells. ×280.

Fig. 2*A*. Outer view of basal portion of left intromittent organ. *B*, coxopodite of leg; *C*, vas deferens, continued by dotted lines *behind* upright portion of organ and entering as shown in 2*B*; *D*, basal portion of anterior section of organ; *E*, posterior section of organ, attached to succeeding abdominal segment; *F*, spur on posterior section, fitting into socket in anterior. Natural size.

Fig. 2*B*. Inner view of anterior section of intromittent organ, showing manner of vas deferens and continuation of the organ into the long copulatory portion. Natural size.

Fig. 3. Reproductive organs of immature female, with triangular abdomen. *A*, sperm sacs; *B*, ovaries; *C*, digestive gland; *D*, stomach.

Fig. 4. Reproductive organs of adult female shortly after copulation, showing enlarged size of sperm sacs. Lettering as in figure 3.

Fig. 5. Empty shell from which egg has hatched. ×280.

Fig. 6. Sperm sac of female after jelly which carried spermatophores from the male into it has disappeared, leaving the spermatozoa in the white ridge, *A*. *B*, anteriodorsal opening to ovary; *C*, opening to oviduct. Natural size.

Fig. 7. Small portion of sponge, showing manner of attachment of eggs. *A*, hair; *B*, covering of hair and tendril. Unstained. ×280.

Fig. 8. Spermatophore in which the spermatozoa are carried from the male to the sperm sacs of the female. ×280.

Fig. 9*A*. Spermatozoa from vas deferens of male, after treatment with Bouin's fixing fluid and mounting on slide.

Fig. 9*B*. Spermatozoa from the sperm sacs of females, some of which had previously spawned one batch of eggs.

Fig. 10. Hair from swimmeret of blue crab, bearing empty shells of the eggs from which the young have hatched. The presence of such fragments of a sponge upon the swimmerets of a female crab is proof that she has spawned at some time. Individuals may be found in considerable numbers with such remnants during the winter and spring months. ×25.

Fig. 11. Reproductive organs of male crab. *A*, testis; *B*, gland secreting medium for transporting spermatophores; *C*, vas deferens; *D*, stomach; *E*, digestive gland. ×½.

Fig. 12. Egg taken from ovary and kept for 15 minutes in sea water; note swelling, manifested by distension of egg membrane; *A*, egg membrane.

Fig. 13. Reproductive organs of adult female crab taken with the dredge on January 5, 1917, in Chesapeake Bay. *A*, ovaries, large, and filled with mature eggs. The sperm sacs are covered by the ovaries at this stage. ×½.

PLATE XLIX.

Fig. 14. Ventral view of adult male crab showing copulatory organs.

Fig. 15. Copulatory organs of male crab. Black paper has been placed behind the ducts leading from the reproductive organs. *A*, vas deferens, duct leading from the testis out through the inner joint (coxopodite) of the leg to the intromittent organs; *B*, intromittent organs.

Fig. 16. Ventral view of adult female crab showing swimmerets. *A*, inner swimmerets to which the eggs are attached; *B*, external openings of oviducts. × ½.

PLATE L.

Fig. 17. Photograph of reproductive organs of female crab shortly after copulation, showing sperm sacs large and distended by the jelly carrying the spermatozoa from the male. *O*, ovary; *S*, sperm sacs; *L*, digestive gland.

Fig. 18. Photograph of female crab upon whose swimmerets remnants of an old sponge were found, thus showing that the individual had spawned. This crab was taken with the dredge on February 28, 1917, in Chesapeake Bay. Note large, full appearance of ovaries, *O*, which are filled with mature eggs; *L*, digestive gland.

Fig. 19. Female crab bearing what is known to be at least the second sponge. Remnants of an old sponge were found upon the swimmerets when she was taken on April 24. This individual was kept under observation in a wire cage in the water of Hampton River. On May 30 this sponge was formed. Microscopic examination during the next few days showed that the eggs were fertile and beginning to develop. × ⅔.

PLATE LI.

Fig. 20. Floats secured within an inclosure of wire supported on posts to prevent disturbance by boats.

Fig. 21. Zoëa, form possessed by the blue crab when first hatched. (After Brooks.) × 80.

Fig. 22. Four crabs which were taken with the dredge during the spring of 1917 and which spawned in June of that year. The three without claws were kept under observation in a cove at Lynnhaven Bay, Va. The one with the claws was kept in a wire cage in the water of Hampton River, Va. The two at the left are known to have spawned the preceding season as remnants of an old sponge were found upon the swimmerets of each of them when caught.

Fig. 23. Megalops, second form of the blue crab, attained after molting from the zoëal stage. (After Brooks.) × 80.

Fig. 24. Regeneration of the claws. When this individual was caught the left claw was lacking. At the first molt while in captivity the claw was regenerated, upper row; in the two succeeding molts the left claw practically overtook its fellow in size, middle and lower rows.

PLATE LII (After Hay).

Fig. 25. "Buster" crab, first molting stage.

Figs. 26, 27, 28, and 29. Successive molting stages.

Fig. 30. Photomicrograph of eggs attached to hairs of swimmerets. A few empty shells from which the young have been hatched are shown. In many of the eggs, the eyes of the developing zoëas may be seen. × 120.

PLATE LIII.

Fig. 31. Dorsal view of adult female crab.

Fig. 32. Ventral view of immature female crab, with triangular abdomen.

Fig. 33. Ventral view of adult female crab, with broad abdomen.

PLATE LIV.

Fig. 34. Dorsal view of adult male crab.

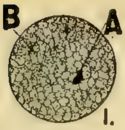
Fig. 35. Ventral view of adult male crab.

Fig. 36. Crate containing adult crabs for observation. It measured 2 by 2 by 4 feet and consisted of an iron frame covered with chicken wire fencing with a 1-inch mesh. It was divided into four vertical compartments to prevent the crabs crowding together and to prevent the escape of all the crabs in case the wire was torn at any point. A wire bail was attached at each end and brought together over the top in the middle. To their point of union a wire was secured by which the crate was lowered and raised.

PLATE LV.

Fig. 37. Type of float which was used in the experiments with adult crabs.

Fig. 38. Wire cages in which molting crabs were confined for observation. The cages rested on the bottom within the inclosure shown in figure 20, each being raised and lowered by means of an individual wire, the upper end of which was attached to a post at a point above high-water mark.



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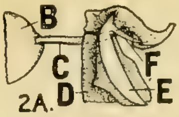

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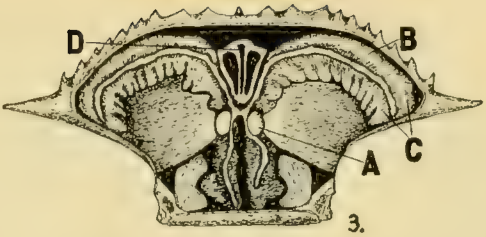

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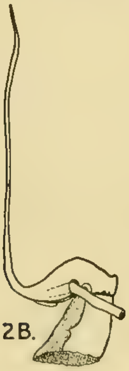

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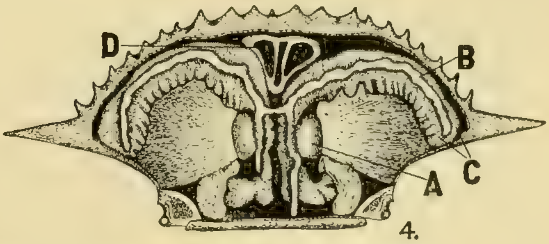

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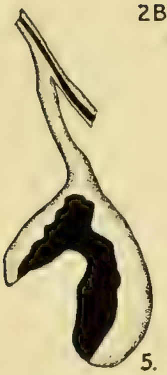

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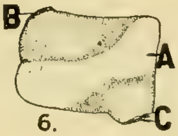

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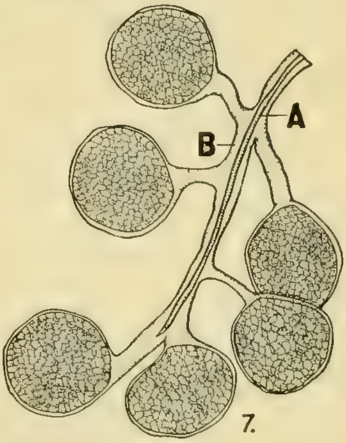

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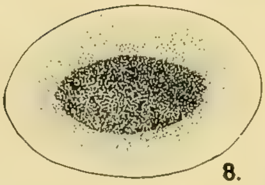

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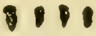

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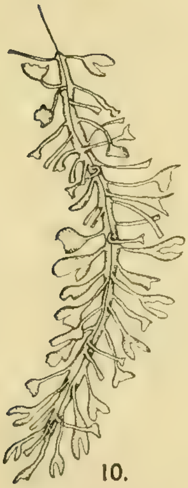

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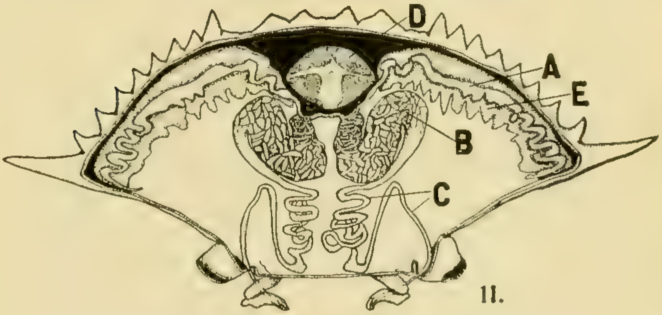

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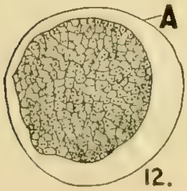

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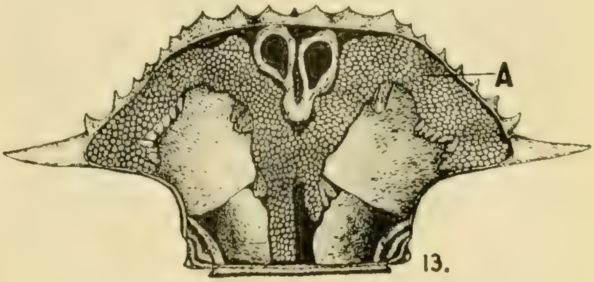

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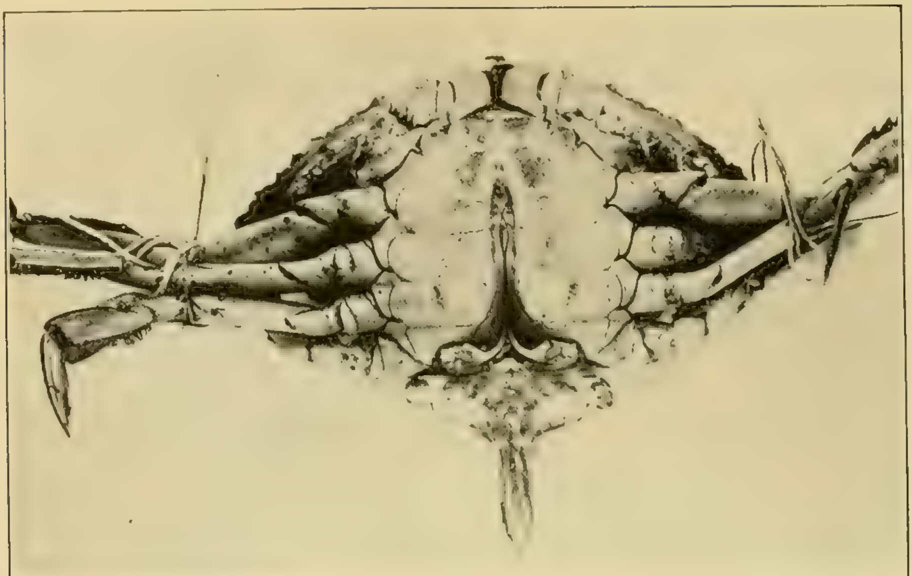

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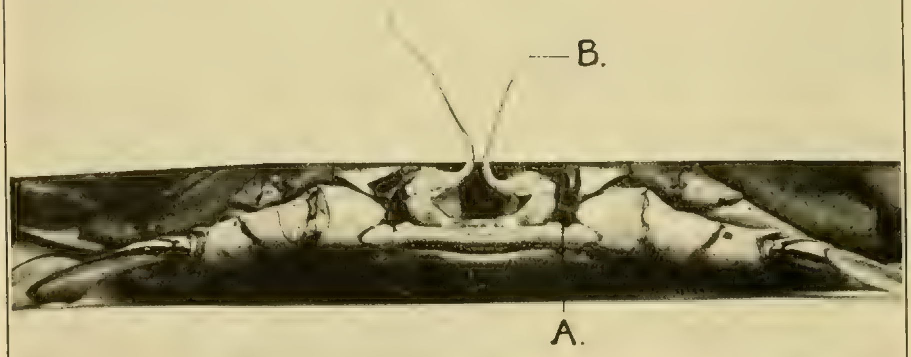

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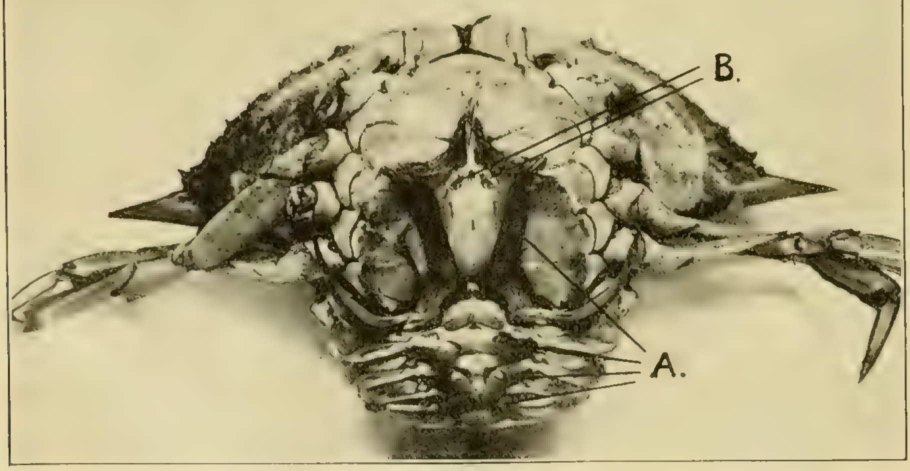

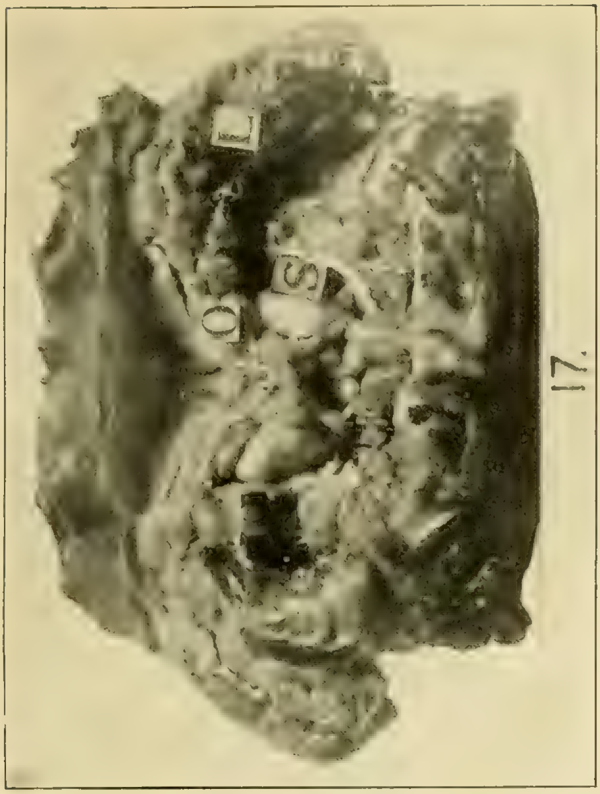

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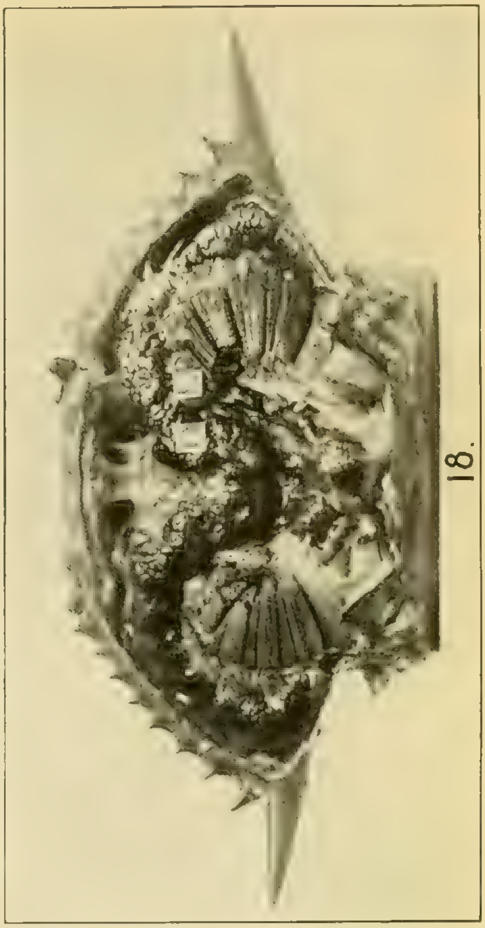

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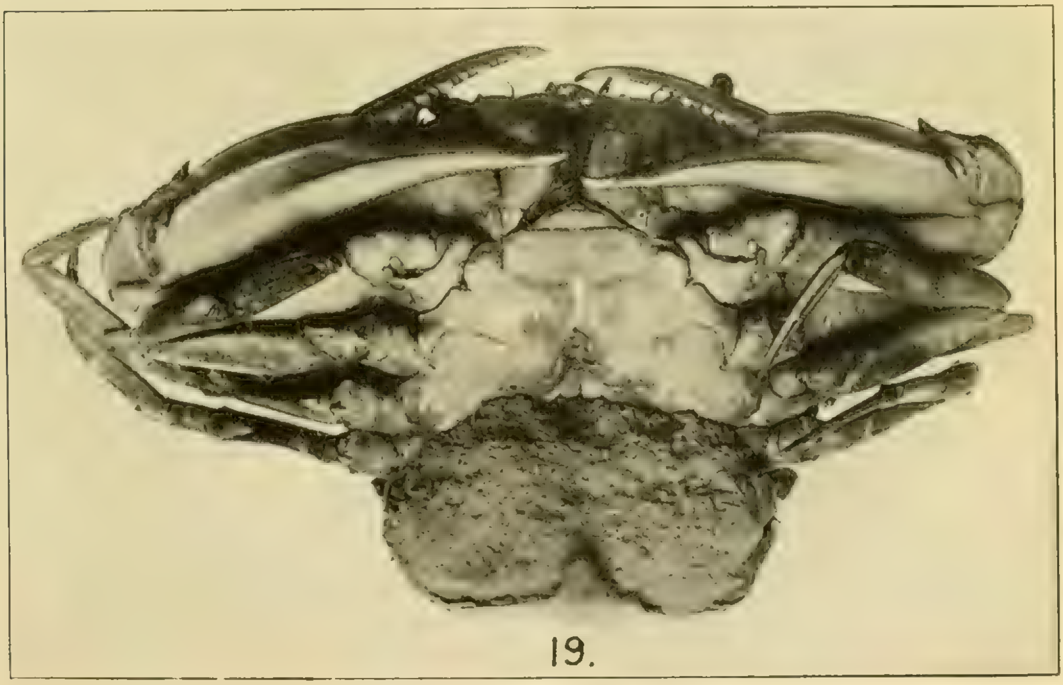

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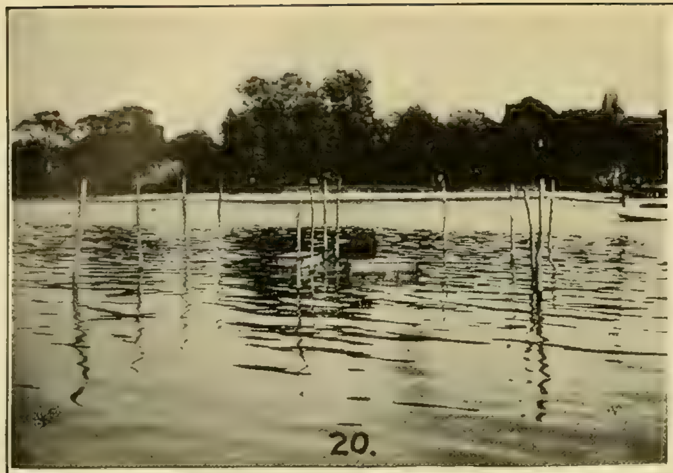

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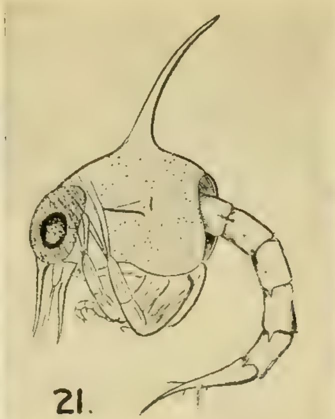

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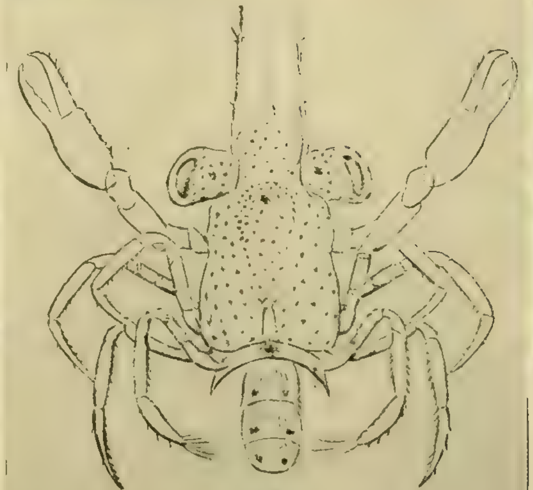

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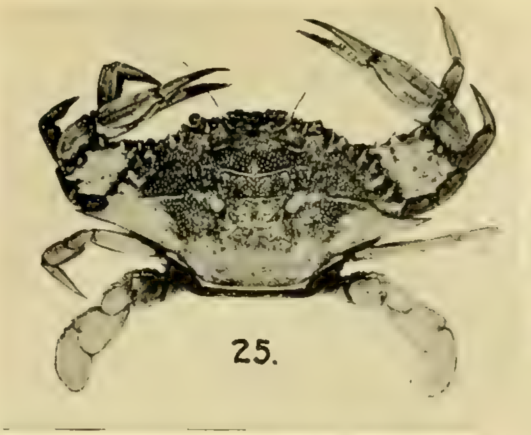

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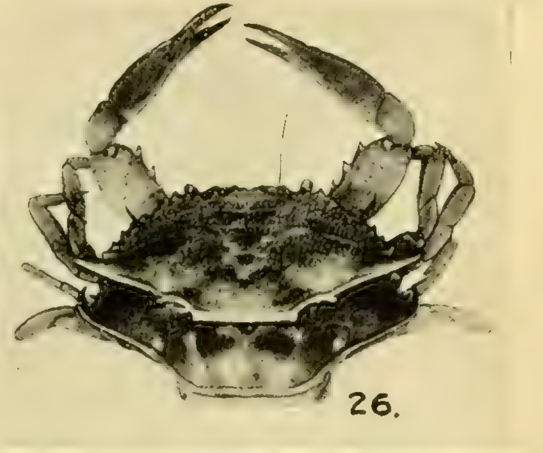

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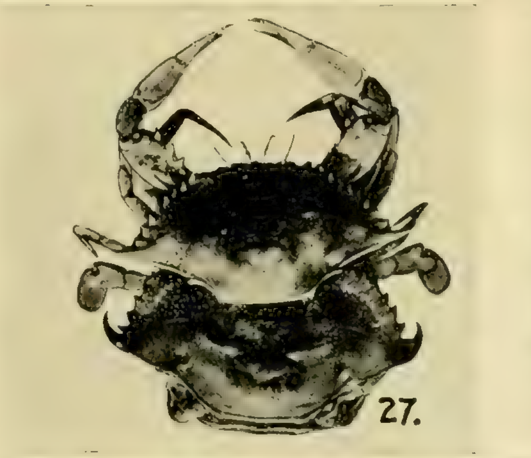

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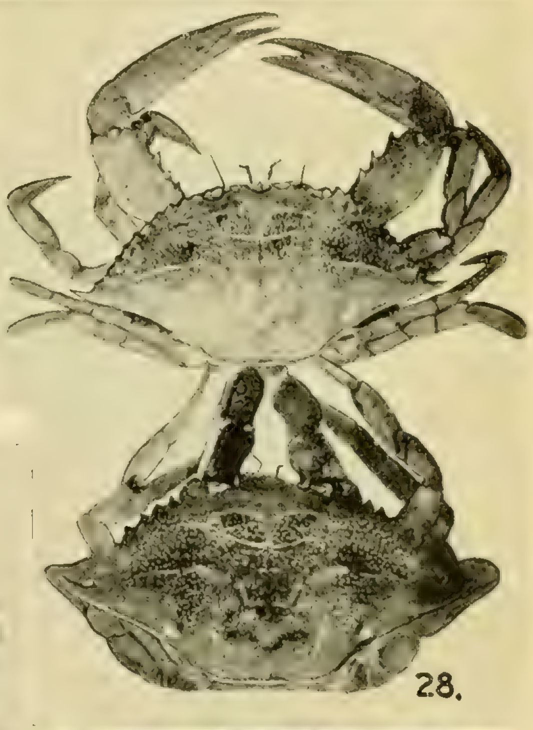

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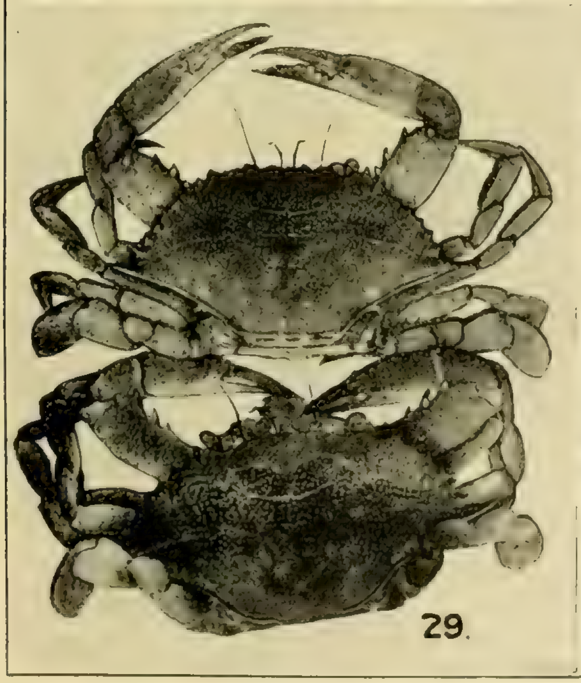

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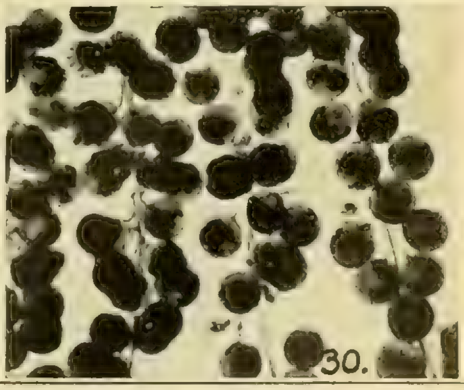

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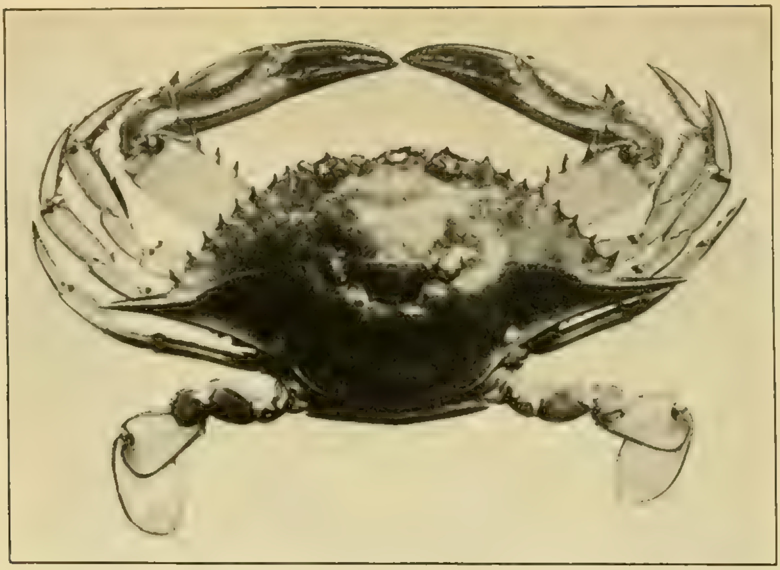

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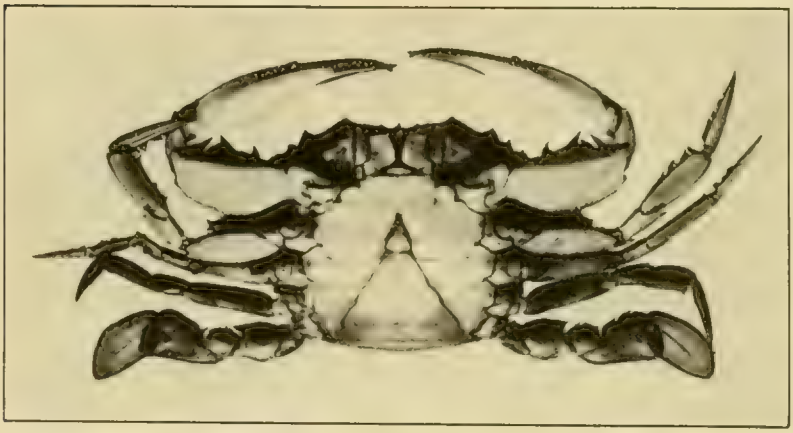

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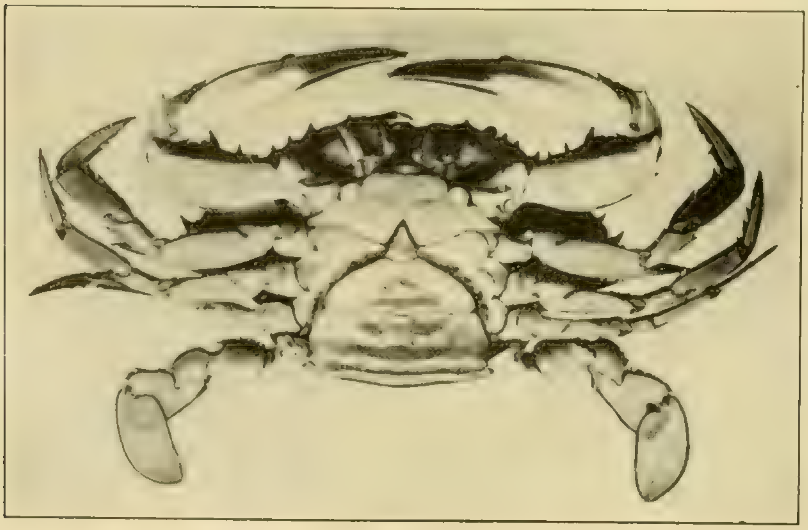

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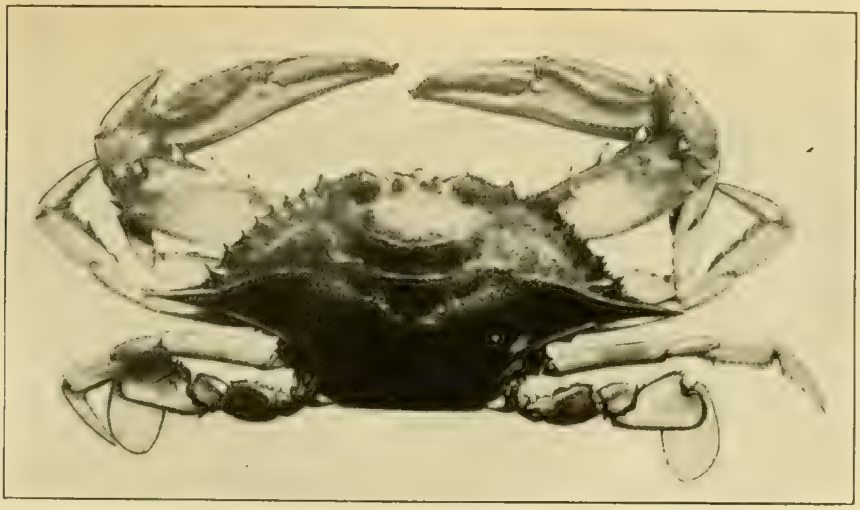

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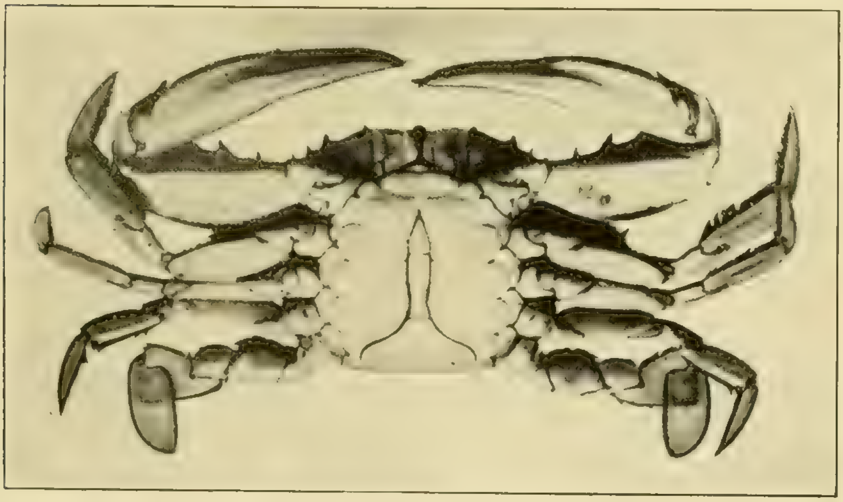

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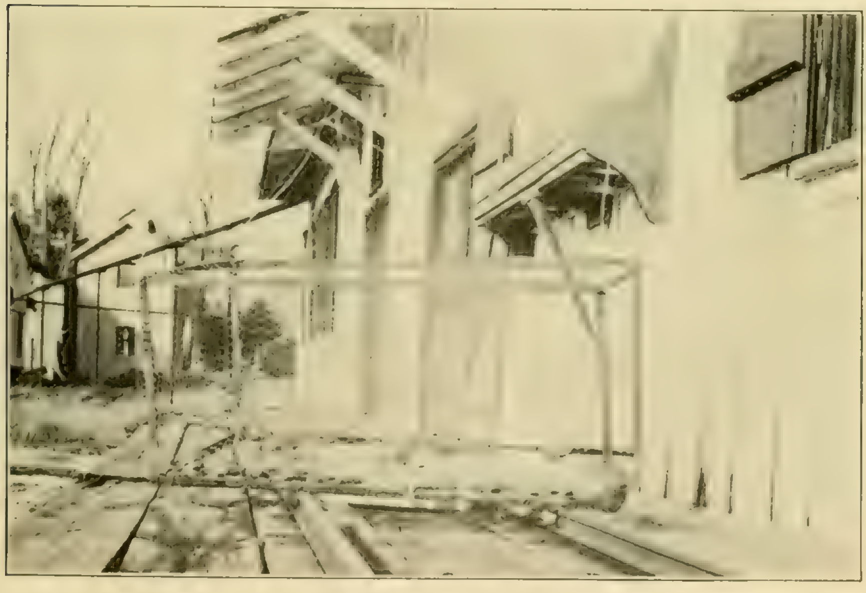

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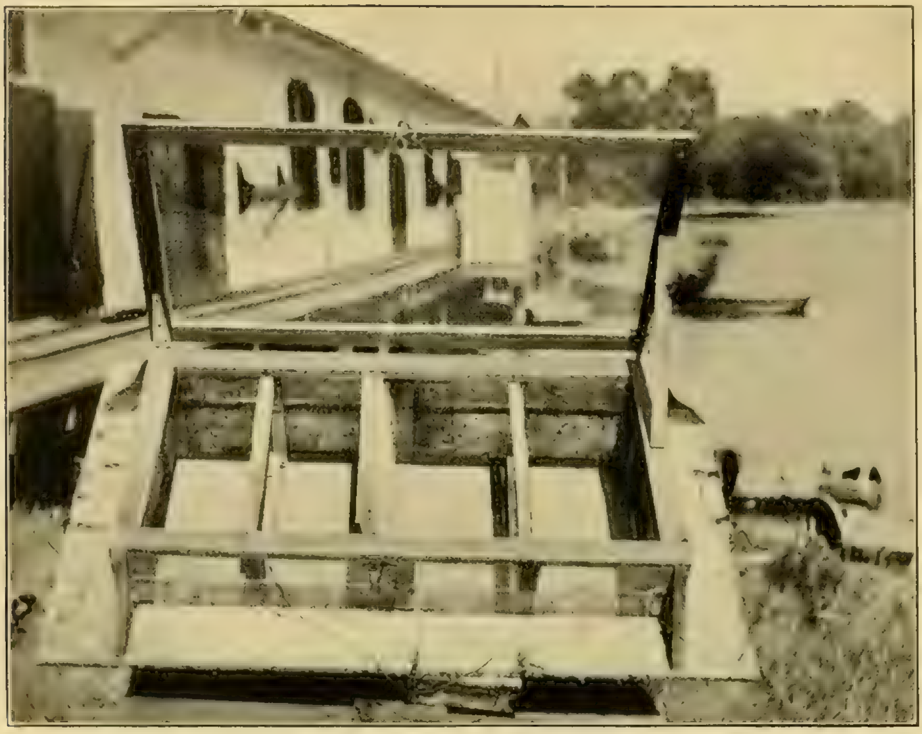

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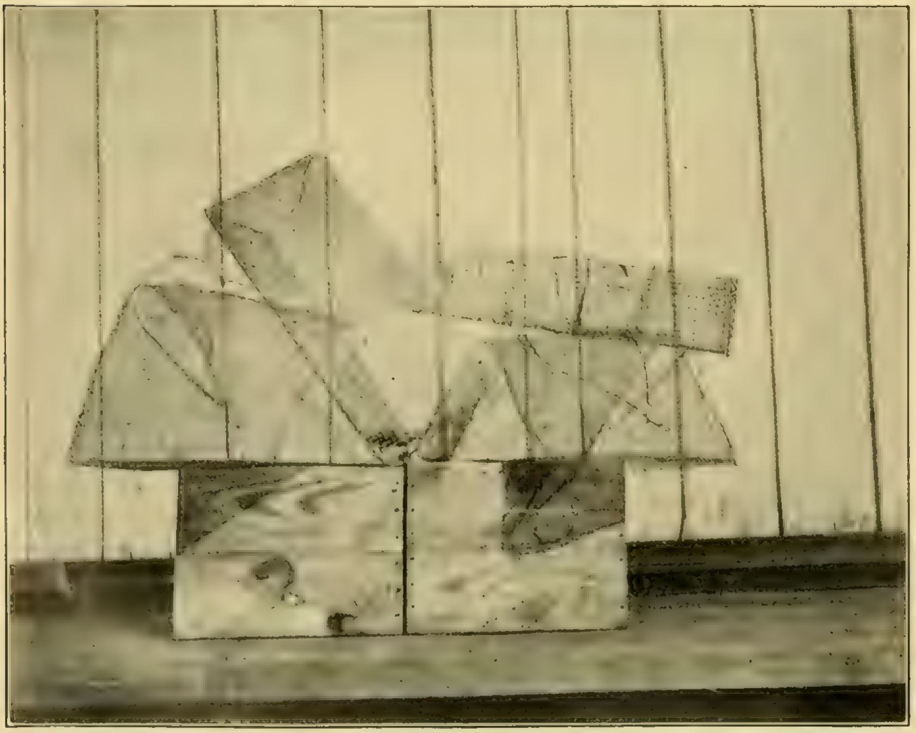

38.

SPONGES OF BEAUFORT (N. C.) HARBOR AND VICINITY

* * *

By W. C. George
Late instructor in Zoology, University of North Carolina
and
H. V. Wilson
Professor of Zoology, University of North Carolina

FOREWORD.

The present paper by Messrs. George and Wilson on Sponges of Beaufort (N. C.) Harbor and Vicinity is one of a series of papers dealing with the different groups of animals and plants inhabiting the waters in the neighborhood of the U. S. Fisheries Biological Station at Beaufort, N. C. Soon after the Beaufort laboratory was established for practical service to the fisheries, it was determined that one of the essential foundations for such service was an exact knowledge not only of the directly useful fishes and shellfishes, but of all animals and plants inhabiting the region and necessarily having some relation to fishes and shellfishes as food, as enemies, as competitors, or as affecting their existence in other ways. A series of sympathetic studies was therefore started simultaneously with the beginning of activities in practical fishery experiment work. While none of the sponges of the Beaufort waters are now known to have a positive economic value, some of them are encountered as direct or indirect enemies of oysters. Other species have served as a basis for experimental work which may have a bearing upon sponge culture in other waters. A final appraisal of the significance of the sponges in such waters can not, however, be made in the present stage of our knowledge. This report contributes to the desired foundation of knowledge, and its publication by the Bureau is desirable.

H. M. Smith,
Commissioner of Fisheries.

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SPONGES OF BEAUFORT (N. C.) HARBOR AND VICINITY.

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INTRODUCTION.

The following report includes a description of the forms of sponges which are present and in any degree conspicuous in the Beaufort area. The collections were made from time to time, especially between the years 1904 and 1907. Doubtless additional forms will be recorded. It is especially probable that intensive examination of "oyster rocks" and scattered shells will result in the discovery of other small, inconspicuous species, comparable in this respect to *Pleraplysilla latens*, herein described. Considering the interest and value for experimentation of Pleraplysilla, a horny sponge of exceedingly simple character, such a search would be well worth undertaking. Collecting along the sea beaches has been incidental. Most of the material so collected proved unfit for precise study. Such sponges, in fact, are usually macerated, the microscleres lost, and the cellular tissues destroyed. The "Fishing Bank" off Beaufort Inlet has yielded specimens of four species. Collecting here, however, has been casual only, and the bank is probably the home of many more species. This bank is of a coralline nature, with a fauna which appears to be West Indian. It lies about 20 miles southwest of Beaufort and has been charted by the U. S. Bureau of Fisheries steamer *Fish Hawk.*

Of the 17 forms described in this paper, those especially available for biological investigations of an experimental nature are species of Cliona, Suberites, Tetilla, Reniera, Stylotella, Lissodendoryx, Microciona, and Pleraplysilla, representing chiefly the two great monaxonid groups, but including also a tetractinellid species and a horny sponge. It is quite possible that some of the other forms, especially the species of Spirastrella, Esperiopsis, and Hircinia, might be made use of for such investigations. These species occur in some abundance on the "Fishing Bank" and perhaps nearer the inlet. With care, living specimens, or, at any rate, living pieces which would answer the purpose, might be brought to the laboratory, or certain breeding experiments might be begun on shipboard, and the cultures handled in the laboratory later.

The scheme of classification followed is, in general, that used by Dendy in 1905. Some alterations which seem to be advisable have been made. In the scheme as here adopted the larger groups of the noncalcareous sponges are as follows:

Order 1. MYXOSPONGIDA.—Simple forms without a skeleton. Absence of the skeleton primitive (Halisarca, Bajalus, Hexadella, Oscarella).

Order 2. HEXACTINELLIDA (Triaxonida).—With triaxonid, characteristically hexactinellid, siliceous spicules.

Order 3. TETRAXONIDA.—The characteristic form of spicule is a siliceous four-rayed sclerite, each ray representing a particular axis (tetraxonid or tetractinellid spicule). But in some groups these spicules have been lost.

Suborder 1. HOMOSCLEROPHORA (Dendy, 1905).—Megascleres and microscleres are not yet sharply differentiated from one another (Plakinidæ, Corticidæ, Thrombidæ).

Suborder 2. ASTROTETRAXONIDA (Hentschel, 1909).—Tetraxonid sponges without desmas, characterized fundamentally by the astrose microscleres, which, however, have been lost in the evolution of some groups.

Tribe 1. ASTROPHORA (Sollas, 1888).—With tetraxonid megascleres and astrose microscleres.

Tribe 2. ASTROMONAXONELLIDA (Dendy, 1905).—Sponge body generally compact and massive, sometimes approaching a definite shape, but also incrusting. Megascleres all monaxonid, often radially, or somewhat radially, arranged. Skeleton rarely fibrous, not distinctly reticulate, and usually without spongin. Microscleres, if present, are asters of some form or other. Presumably derived from the Astrophora through loss of tetraxonid megascleres. Equivalent to Hadromerina, Topsent.

Suborder 3. SIGMATOTETRAXONIDA (Hentschel, 1911).—Tetraxonid sponges without desmas, characterized fundamentally by microscleres which are either sigmata or forms derivable from the sigma. But the microscleres have been lost in some groups.

Tribe 1. SIGMATOPHORA (Sollas, 1888).—With tetraxonid megascleres. Microscleres when present are sigmata.

Tribe 2. SIGMATOMONAXONELLIDA (Dendy, 1905).—Megascleres all monaxonid. Skeleton very commonly reticulate or fibrous, with a good deal of spongin. Microscleres, when present, either sigmata or derived forms such as chelæ. True astrose microscleres are absent, except, possibly, in an aberrant species or two. Presumably derived from the Sigmatophora through loss of the tetraxonid megascleres. Equivalent to Halichrondrina auct.

Suborder 4. LITHISTIDA.—Tetraxonida with desmas.

Order 4. KERATOSA (Euceratosa, Dendy, 1905).—Skeleton made up of horny fibers. Without proper spicules. Absence of spicules primitive and not due to evolution by loss. Sand grains and other foreign mineral particles often aid in forming the skeleton, and in exceptional cases constitute its chief part.

The families, subfamilies, and genera represented are defined in the text. In constructing these and the above definitions we have freely used the memoirs of Dendy, Lendenfeld, Lundbeck, Sollas, Topsent, and Vosmaer. A consideration of some comparative data, falling for the most part under the head of variation, together with a discussion of the facts on which the genera are made and classified, has considerably lengthened the sections assigned to several of the species. This matter follows, in each section, the description of the species, from which it is more or less conspicuously set off.

ASTROMONAXONELLIDA Dendy.

Family SPIRASTRELLIDÆ.

Megascleres usually styles or tylostyles, sometimes diactinal. Asters of various forms occur, often forming an ectosomal crust.

Spirastrella O. Schmidt.

Sponge incrusting, or cushion-shaped with processes, or massive; or vase-shaped with large cloaca, in which case the incurrent and excurrent surfaces may be differentiated. Megascleres styles or tylostyles, or a mixture of the two forms. Microscleres usually present, and abundant, in the form of spirasters, but these spicules may be exceedingly scarce, or even wanting.

Spirastrella andrewsii, n. sp. (Pl. LVI, figs. 3, 6, 7*a*, *b*; Pl. LXVI, fig. 49*a*, *b*, *c*, *d*.)

A specimen was trawled August 1, 1914, in 15 fathoms of water by the *Fish Hawk* on the "Fishing Bank" off Beaufort Inlet, Fish Hawk station 8199. Since 1914 the *Fish Hawk* has taken in her summer dredgings several very similar specimens in the same locality. Several specimens of the species, now in the National Museum at Washington, were taken by the *Albatross* off the Carolina coast at a depth of about 30 fathoms during the summer of 1885. The species has also been taken in Jamaican waters by Prof. E. A. Andrews.

The striking characteristic features of the sponge are its large size, habitus, and the differentiation of incurrent and excurrent surfaces. The sponge is cylindrical, with large cloacal cavity. Living specimens occur that are high and vaselike. The dried specimens, which, doubtless, have all collapsed more or less, are comparatively low and cushionlike. The external surface of the sponge is incurrent, the cloacal surface excurrent.

The following description is based on the specimen taken in 1914. The sponge is cushion-shaped, 60 centimeters across and 30 centimeters high; cloacal cavity 30 centimeters across at the mouth, 20 centimeters deep. The color is dark brown at the surface, lighter within. Consistency in an alcoholic specimen is like firm, dense cartilage, sponge becoming woody on drying. Whole sponge is greatly excavated by canals which contain many shrimp. The lateral surface is closely studded with small incurrent apertures (fig. 7*b*), which measure 1 to 2 millimeters in diameter. The upper surface around the mouth of the cloaca shows irregular areas of similar apertures. They are all actual openings, not closed by pore membranes. Beneath the ectosome of the lateral and upper surfaces the sponge is cavernous, with large canals 6 to 8 millimeters wide, or even larger, extending more or less radially into the interior. Several incurrent appertures, perforating the ectosome, lead into each canal. On the walls of these great canals are abundant apertures leading into surrounding small canals.

The external surface of the sponge between the incurrent apertures appears to the eye comparatively aporous. It is, however, dotted with abundant small, round subdermal cavities, for the most part 200 to 300 μ in diameter, but as small as 80 μ in diameter. The thin, dermal membrane covering these cavities is perforated by pores 40 to 50 μ in diameter, one to a few (about 3 to 4) pores leading into each cavity. The membrane roofing in a subdermal cavity contains spirasters, but is free from megascleres, excepting such as project into it from the surrounding tissue. The subdermal cavities are produced into small canals which pass inward, as may best be seen in a series of thick tangential sections.

The anatomy suggests that the large incurrent canals serve to carry water directly into the deeper interior of the sponge, while the external region is fed by small canals, some of which arise as branches of the larger and others of which arise between the incurrent apertures, as just described. It is needless to say that observations on the living sponge in this connection are desirable.

The cloacal wall is studded with oscula, 4 to 5 millimeters in diameter and smaller, although the smaller sizes are obviously often due to partial closure (fig. 7*a*). Oscula are numerous, the distance between fully open ones being less than the oscular diameter. Each osculum, which, with its surrounding rim of "oscular membrane," forms a circular depressed area in the dried sponge, is the aperture of a large efferent canal extending more or less radially into the sponge substance. The efferent canals in this specimen are somewhat smaller than, and not so close together as, the corresponding incurrent canals; but this is a matter of individual variation.

Numerous very small subdermal cavities, covered in by dermal membrane, underlie the cloacal surface between the oscula. Some are circular and about 80 μ in diameter; others are elongated and about 200 μ across. From them small canals, often about 80 μ in diameter, pass radially into the interior. (Sponge being shrunken, such dimensions are, of course, far from what they must be when the sponge is expanded.) The areas of dermal membrane covering in the subdermal cavities are thin and in life are doubtless perforated by the (now closed) pores. In correlation, perhaps, with the completely closed condition of the pores and the contracted state of the sponge these areas now contain megascleres scattered tangentially. The inference to be drawn from the anatomy is that the cloacal surface is not an exclusively excurrent surface.

Spicules.—Megascleres: (1) The characteristic spicule is a tylostyle (fig. 49*c*), smooth, slightly curved, about 350 by 8 μ. The common range in length is 325 to 425 μ· in thickness, 7 to 11 μ. The head may be evenly rounded, or it may be somewhat elongated and bear a constriction. Modifications of this spicule sometimes occur in the form of (2) tylostyles (fig. 49*a*), in which the apex is not pointed, but rounded, and (3) styles (fig. 49*b*). Microscleres: Spirasters (fig. 49*d*), 8 to 20 μ long, of one or two complete "turns." The spines are short and conical, sharp in some spicules, truncated and blunt in others. The spicules occur at the dermal and cloacal surfaces and in the walls of the canals. They are abundant, but not very abundant; nowhere do they form a continuous layer or "crust," but everywhere they are spaced well apart. The common range of length in the spicules at the dermal and cloacal surfaces is 8 to 12 μ. In the walls of the large canals they reach 20 μ in length.

Skeletal framework.—The septa of sponge tissue between the canals are well filled with megascleres except in the region immediately around a canal. In places the megascleres lie crossing one another in all directions. But in many septa, both thick and thin, the spicules all lie about in the same direction and are compactly arranged, thus constituting a fairly distinct tract. Different tracts cross one another at various angles, connecting and branching, and thus give to the skeleton a fibrous appearance which is inconspicuous in alcoholic, but conspicuous in dried, material. In the canal walls the megascleres are strewn thickly and tangentially.

At the dermal surface, while there are some tangentially placed spicules, the bulk of the megascleres occupy an obliquely radial or radial position, their points projecting; but they are not divided into distinct brushes. They form a continuous covering, which is only interrupted by the large, incurrent apertures and the areas of membrane over the small, subdermal cavities.

At the cloacal surface also many megascleres lie radially and obliquely, projecting slightly. At this surface there is in this specimen a particularly dense skeletal layer, about 1 millimeter thick, in which the spicules lie in all directions. This is a detail which is not present in all the specimens.

The first specimen of this species studied by us was collected a number of years ago in Jamaican waters by Prof. E. A. Andrews, of Johns Hopkins University. Some data concerning this specimen may be recorded here. The characteristic size of the tylostyles is 420 μ by 14 μ. The spirasters at the dermal surface are commonly about 14 μ long and are more abundant than in the Beaufort specimen, forming a continuous crust. In the walls of the larger canals they reach a length of 20 μ.

In the dried fragment of this specimen sent us for examination, the incurrent apertures of the dermal surface were for the most part filled with what were doubtless small anemones. Dendy records (1896, p. 252) that in *S. papillosa* R. and D., occurring in the neighborhood of Port Phillip Heads, Australia, "the surface is sometimes much infested by a parasitic actinozoan."

The habitus of the Jamaican specimen as recorded by Prof. Andrews is interesting: "Height of sponge, 2 feet; diameter, 11 inches; diameter of mouth, 4 inches; depth of cloacal cavity, 10 inches. Sponge stood upright on a reef 20 feet below the surface. In life the color was black or perhaps purplish black, very dark brown when dried. When alive, sponge was covered with peculiar small objects which seem to be actinians, partly embedded in the surface, each 1 millimeter in diameter. Sponge hard, smooth, compact."

The *Albatross* specimens in the National Museum "average 18 inches in diameter, 12 inches high; cylindrical in shape, but with deep cavity in top." (Letter from Dr. Mary J. Rathbun of the U. S. National Museum.) A particular specimen measured 30 centimeters high by 40 centimeters in cross diameter; cloacal cavity 15 centimeters deep, 25 centimeters across at the mouth. The sponge (dried) is hard and woody. Color, dark brown at surface; canalar walls not so dark; parenchyma whitish gray. Large canals 6 to 7 millimeters in diameter, up to twice that size, extend in from both dermal and cloacal surfaces.

A fragment of this specimen was examined microscopically. The tylostyles had a distinct but only slightly developed head; measured 414 to 468 μ by 11 to 14 μ; were in general slightly and evenly curved, but sometimes bent more or less abruptly. The spirasters were commonly 10 to 12 μ long. In respect to the abundance of the spirasters at the dermal surface, the specimen (fragment) proved to be intermediate between the Beaufort and the Jamaican sponges.

The vaselike habitus with differentiated incurrent and excurrent surfaces has not hitherto been described in Spirastrella. The nearest approach is made by the type specimens of *Spirastrella* (*Alcyonium*) *purpurea*, collected by Peron and Lesueur in 1803 in Australian waters and first described by Lamarck in 1815. Topsent, who in recent years has reexamined these specimens (1906*a*, p. 3), thinks that one, at any rate, possibly represents a marginal fragment of a vasiform sponge. The two faces are different. One, which Topsent suggests may be the outer surface, is imperforate and bears radial tuberosities, while the other bears orifices visible to the eye about 1 millimeter apart. The interior of the sponge is porous but not cavernous.

Vosmaer (1911) has shown that a great number of forms described from many parts of the world intergrade in respect to any of the points he has considered. He hence combines them all as one species, which he designates *S. purpurea* (Lamarck). It may be doubted if the name is well chosen; certainly not if Topsent's interpretation is correct and Lamarck's fragments belong to a vasiform sponge with differentiated faces. This would be very different from the remainder of those combined by Vosmaer, and a new name would thus be necessary for Vosmaer's species.

Certain gross anatomical points of resemblance between *S. andrewsii* and Poterion are obvious. These are the vasiform shape and the differentiation of pore and oscular surfaces. But the pore areas and afferent canal system of *P. atlantica* are quite different structures from the incurrent apertures and great canals of *S. andrewsii*, and the oscula and oscular canals of the two forms are likewise very different. The resemblance is only the gross likeness which results from the sponges independently acquiring the same shape of body and the same type of distribution of the incurrent and excurrent orifices.

While *S. andrewsii* is a striking species in the matter of size, one species of the genus already is recorded that exceeds it. This is the great *Hymeniacidon pulvinatus* of Bowerbank (1872, p. 126), which Vosmaer (loc. cit.) merges into *Spirastrella purpurea* (tropus *pyramidalis*). This sponge, occurring at Calebert Quay near Belize (British Honduras), is a massive, sessile form reaching 8 feet in height. The oscula and pores are scattered over the surface. The sponge is cavernous with large canals.

Position of the genus.—The spiraster of Spirastrella has generally been regarded as a modified aster, and the genus accordingly put in the Astromonaxonellida (Hadromerina of Topsent). But Vosmaer (1909) has concluded that the spicules are spiral monaxons with spines, since the latter contain no axial canals, as do the actines of a true aster. Dendy (1916, p. 96), perhaps reasoning from this fact, transfers the Spirastrellidæ, and along with them the Clionidæ and Suberitidae, to the Sigmatotetraxonida. Awaiting Dendy's detailed reasons for the change, the families are retained in this paper in their old position.

Family CLIONIDÆ.

Astromonaxonellida that bore into and excavate molluscan shells and other calcareous bodies.

Cliona Grant.

The complete spiculation includes tylostyles, oxeas, and spirasters. Of these elements one or two fail to appear (undergo atrophy) in certain species.

Cliona celata Grant. (Pl. LVI, figs. 2, 4, 5; Pl. LXVI, fig. 50.)

Spongia sulphurea, Desor, 1848, p. 67.
Cliona sulphurea, Verrill and Smith, 1874, p. 450.
Cliona sulphurea (Desor), Leidy, 1889.
Cliona celata Grant, Lambe, 1896, p. 202.
Cliona celata Grant, Topsent, 1900, p. 32. (Synonomy here given in full.)

A common sponge in Beaufort Harbor, especially occurring in oyster and clam (Venus) shells. The specimen figured was taken just below low-water mark from the edge of a little island.

The sponge consists of anastomosing trabeculæ (Pl. LVI, fig. 5), which lie in the body of the shell, and numerous projecting tubular papillæ bearing pores or oscula. The sponge trabeculæ completely fill the excavations in the shell, and in an old specimen the excavations occupy nearly all the space between the thin shell walls. The papillæ may be extended a few millimeters, or may be retracted into the shell. They are of two kinds: (1) Pore papillæ, which, when extended, have a tubular stalk with a mushroom-shaped cap covered by a dermal membrane riddled with pores 15 to 35 μ in diameter. No pores were found except over the expanded end of these papillæ. The diameter of the tubular stalk of the pore papillæ in a preserved specimen is 1 to 2 millimeters and the diameter of the expanded end 1.5 to 3 millimeters. They connect with the trabeculæ in the interior of the shell. (2) Very similar tubular papillæ, each bearing a single terminal osculum 1 to 1.5 millimeters in diameter, instead of a porous cap. In the living specimen, observed in shallow aquaria, the oscular papillæ are found to be conical at the tip and are easily distinguished from the pore papillæ, with which they are intermingled over the surface of the shell. They are few in number as compared with the pore papillæ.

Coarsely granular or spheruliferous cells (*cellules sphéruleuses*) are exceedingly abundant, as in the sponges examined by Topsent (1900).

Spicules.—Tylostyles, smooth, slender, slightly curved, with a pretty sharp point, measuring 200 to 400 μ by 4 to 9 μ. The spicules taper slightly toward the head end, as well as toward the point. The curvature is in the upper (head) half of the spicule.

Skeletal framework.—The skeleton of the sponge trabeculæ within the shell consists of irregularly scattered, moderately abundant tylostyles. The skeleton in the wall of the tubular pore papillæ consists of a dense confused network of tylostyles, some of which have their points extending slightly beyond the dermal membrane. At the distal end of the papilla, where the pore-bearing cap spreads out, the reticulum of the wall breaks up into a system of loose fibers and trabeculæ, which extend upward at various angles, spreading out terminally in brushes to support the dermal membrane which covers the cap. The skeleton of the wall of the oscular papilla likewise consists of a dense reticular mat of spicules. As we approach the tip of the papilla the mat becomes less dense, and the spicules point more toward the tip, becoming arranged frequently in more or less definite plumose tracts. There is no spongin.

At the base of the pore and oscular papillæ there is a sharp contrast between the dense skeleton of the walls of these tubes and the loose skeleton of scattered spicules in the trabeculæ within the shell.

This sponge, as is well known, may grow out of the shell which it has excavated and eventually form a free mass of large size. But the massive phase, which is common on the New England coast, where it may reach a diameter of about 8 inches (Verrill and Smith, 1874, p. 127), has not been observed in Beaufort harbor. Farther south, on the west coast of Florida, the free phase (*Raphyrus griffithsii* Bow) is known to occur, both in the common massive form and in a branched tubular form (!) (Carter, 1884, p. 207).

Topsent (1889; 1900, pp. 34, 55) has concluded that there is no valid reason for maintaining the American form (*Spongia sulphurea* Desor) as a species distinct from *C. celata*. This, in fact, seems to be the case, although a careful and detailed comparison of specimens from the two sides of the Atlantic would in all probability show certain constant, if minute, differences. The Beaufort specimens examined do differ from the European individuals (comp. Topsent, 1900) in the following points: (1) The inhalent papillæ are tubular except at the very top, where the trabeculæ which pass out from the wall to support the pore membrane encroach upon the axial cavity. In the European sponges (Topsent, loc. cit., pp. 35, 47) these papillæ are filled with tissue except basally, where they are hollow. (2) In the Beaufort specimens the head of the tylostyle only rarely exhibits a distinct apical prolongation, whereas this is the rule in the European sponges (Topsent).

Topsent (loc. cit.) gives the range in size of the tylostyles as 180 to 360 μ by 3 to 9 μ. The range in size for the Beaufort specimens is close to this. Moreover, the shape of the spicules is the same, except for the above-mentioned detail, in the two sets of specimens. In the European sponges this is the only spicule that usually occurs. In very young specimens, chiefly in the papillæ, Topsent finds, however, spinose spirasters. But these spicules soon cease to be formed. No such very young specimens have been studied on this side of the Atlantic. In some European individuals of this species long, slender, smooth oxeas, generally in fascicles, occur. Sollas has grouped these as *var. linearis*, but Topsent thinks the point is only a character such as separates individuals and is not the mark of a subgroup.

Poterion Schlegel.

Beginning as a boring sponge, the body becomes free, large, and vase-shaped, with the incurrent apertures on the outer surface and the excurrent apertures on the inner or cloacal surface. Skeleton made up of tylostyles.

Poterion atlantica, n. sp. (Pl. LVI, fig. 1; Pl. LXVI, fig. 51*a*, *b*, *c*.)

A single specimen was trawled by the *Fish Hawk* on the "Fishing Bank" off Beaufort Inlet at a depth of 14.5 fathoms.

The sponge is vasiform, about 12 centimeters across at the top. The vasiform cavity extends entirely through the sponge, which, however, has had its base torn off. Actual height of the specimen is 11 centimeters. The height of the uninjured sponge was probably considerably greater.

The outer surface exhibits contiguous, or nearly contiguous, circular, or irregularly rounded areas about 5 millimeters in diameter. These in the preserved specimen are slightly depressed. The central and greater part of each area is porous and recticular, as seen with the lens and even with the eye, this part measuring about 3 millimeters in diameter. These are the pore areas. Micropscopic preparations of the surface and sections through the pore areas show that each area includes numerous pores 75 to 100 μ in diameter. From each pore a canal of about the same diameter passes vertically into the cortex. The inner surface exhibits similar areas, the center of each occupied by an osculum 0.5 to 1.0 millimeter in diameter. The osculum is the aperture of an oscular (chonal) canal which passes vertically through the cortex.

The sponge has a gray, dense, cartilaginous cortex both on the outer and inner surface of the cup. The surface is now (in the preserved specimen), blackish brown, interior yellow. The interior looks fibrous and is comparatively solid.

Spicules (Pl. LXVI, fig. 51*a*, *b*, *c*).—Smooth, slightly curved tylostyles, 210 to 460 μ by 4 to 8 μ. The head of the spicule may be globular (fig. 51*b*), or there may be a slight constriction around it (fig. 51*a*), or the enlargement may be located a slight distance from the end (fig. 51*c*). There are no microscleres.

Skeletal framework.—The skeleton of the choanosome (Pl. LVI, fig. 1) consists of irregularly scattered megascleres, together with loose spicule tracts. Collections of sand grains occur abundantly in the choanosome. There is a cortical layer 1 to 1.5 millimeters in thickness, composed of compactly and confusedly arranged spicules, which however, in the main, point in a more or less radial direction, sometimes extending beyond the surface. This cortex is pretty definitely marked off from the underlying choanosome, in which the spicules are not nearly so abundant. There is no noticeable difference in the size of the spicules of the cortex and those of the choanosome. At the base of the cortex there is present in most places a thin layer of spicules arranged more or less parallel to the surface (Pl. LVI, fig. 1).

The canals are in general small, mostly 50 to 150 μ in diameter, but some are 500 μ or more in diameter.

The sponge tissue is dense and granular. The flagellated chambers are inconspicuous and measure about 30 μ in diameter.

This interesting sponge is evidently very close to the well-known "Neptune's Cup," *Poterion patera* (Hardwicke), of the Pacific, which Vosmaer some years ago (1908) showed to belong in the Clionidæ. Topsent reviewing Vosmaer's paper (1909) would delete Poterion, merging it into Cliona. But the final structure assumed is such a marked one that the genus should be retained, as Vosmaer more recently has held (1911, p. 3).

Poterion patera, which is not uncommon in the Malay Archipelago, reaches a height of 1 meter, with an aperture of 30 centimeters, the wall of the cup 25 millimeters thick (Vosmaer, loc. cit.). The Beaufort sponge differs from the Pacific species in the larger size and closer grouping of its pore areas. These (Vosmaer, loc. cit.) in the latter form are indistinct in outline, something over 1 millimeter in diameter, and about the same distance apart. The internal skeleton is stronger in the Pacific species than in the Beaufort form, consisting in the former of a firm trabecular network, the trabeculæ made up of closely packed tylostyles and including in the axial region here and there a little spongin (Vosmaer). The spicules in *P. patera* range in size from 450 μ by 14 to 11 μ to 200 μ by 10 to 7 μ (Topsent, loc. cit.).

Family SUBERITIDÆ.

Megascleres tylostyles or styles. Microscleres absent or represented in some forms by centrotylote microstrongyles.

Suberites Nardo.

Body frequently massive, but it may branch or become covered with outgrowing lobes. Without mammiform papillæ. Megascleres nearly always tylostyles. No microscleres. The spicules diminish in size toward the surface. The superficial spicules project radially, and the skeleton, as a whole, may exhibit in some measure a radiate arrangement.

Suberites undulatus, n. sp. (Pl. LVII, figs. 8, 9, 10, 11; Pl. LXVI, fig. 52.)

Fairly common in the muddy pools left at low tide around "Green Rock," in Newport River.

Sponge (Pl. LVII, fig. 8), a speroidal mass, made up of a basal undivided portion and closely set lamellate and narrow, ascending lobes into which the former is produced over its superior and lateral surfaces. A characteristic specimen (the type) measures 60 millimeters in height, with transverse diameters of 75 and 90 millimeters. It was attached below to the shells of live oysters. A few pieces of shell were incorporated in its basal portion, and some algæ grew out from between the lower lobes.

Color light gray. Sponge fairly firm; compressible and easily torn.

The lamellate lobes are all more or less radial, but flattened in various planes. They are thus inclined to one another at all angles. Where they meet they are apt to fuse; this produces cavities closed below and around the sides, which extend into the sponge interior and open above between the free portions of the lobes. The upper margins of the lobes are fairly sharp and have in the alcoholic specimen a dense, whitish appearance. These margins are commonly notched and undulating, but the portions between the notches may be produced into ascending lobules. The central lobes are the longest; their radial length is about one-half the vertical diameter of the whole sponge. Probably the basal part of the sponge mass has been built up during growth through the gradual incorporation of lobes.

The surface when examined with a lens is seen to be minutely roughened and well covered with projecting spicules. The ectosome includes very numerous subdermal cavities, varying considerably in diameter from about 150 μ to 1 millimeter (Pl. LVII, figs. 10, 11). The thin, dermal membrane roofing these over is perforated by pores 20 to 40 μ in diameter, several opening into each cavity. Most of the pores are closed, but enough are open to show the arrangement. Small oscula about 1 millimeter in diameter occur on the upper margin of the lobes. Probably they are naturally numerous, but now for the most part closed.

The interior of the sponge is dense as compared with the ectosome, but sections (Pl. LVII, fig. 10) show that it, too, is greatly excavated by canals, most of which are small, about 100 to 300 μ in diameter, with some larger ones. Flagellated chambers, ellipsoidal and 20 to 25 μ by 30 to 35 μ, are abundant in the choanosome. The thin trabeculæ and sheets of sponge tissue are favorable for histological study.

Spicules.—Tylostyles smooth and slightly curved, with well-developed, rounded head (Pl. LXVI, fig. 52). The shaft is very slightly thicker in the middle than near the head end, tapering at the other end to a sharp point. The head is not infrequently irregular, sometimes constricted near its middle. Range in size for whole sponge, 200 by 6 μ to 460 by 10 μ.

In the interior the larger sizes are abundant, perhaps predominate. The spicules of the dermal skeleton are, in the average, smaller; the common range being 200 by 6 μ to 320 by 8 μ.

Skeletal framework.—The skeleton (Pl. LVII, figs. 9, 10, 11) is made up chiefly of abundant and fairly compact tracts of megascleres, which pursue a rather vaguely radial course in the basal part of the sponge, becoming distinctly longitudinal in the lobes. In a slice of some size through the basal part it is easy to see that, while many individual tracts curve in all directions, the skeleton as a whole exhibits a radial arrangement. The spicules lie more or less longitudinally in the tracts and are abundantly scattered between the latter. Spongin is absent.

From the internal skeleton short tracts are given off which extend outward, usually upward and outward, through the ectosome and terminate in dermal brushes of divergent spicules (fig. 11). The dermal skeleton includes, in addition to the brushes, a good many single, radial, and projecting megascleres and abundant tangential megascleres scattered without order. The spicules of the dermal brushes usually project a considerable distance, often about half the length of the spicule. The spots at which they project are, as a rule, either not elevated, or only slightly elevated, over the surface in general; but in places these spots are elevated high enough to be called "conuli." The difference may in part be due to contraction.

In the upper margins of the lobes, or of the subdivisions of the same, the dermal brushes are so closely set as to form a continuous furze, in which the longitudinal skeletal tracts terminate. It is this dense aggregation of dermal spicules that gives to these margins their whitish appearance in the alcoholic specimen.

The lobes of the Beaufort sponge are, of course, structures quite different from the papillæ of the Polymastidæ.

In its extensive development of the ectosomal canal system *S. undulatus* resembles the species grouped under Topsent's genus Pseudosuberites: *P. sulphureus* (Bean), *P. hyalinus* (R. and D.), *P. andrewsii* Kirkp., *P. exalbicans* Tops. But this particular feature does not, it seems to us, constitute sufficient ground for excluding the sponge from the older genus. Probably when the canal system of the numerous Suberites species has been studied more extensively, considerable variation will be found in this matter within the genus.

SIGMATOPHORA Sollas.

Family TETILLIDÆ Sollas.

The characteristic megascleres are protriænes, which may be very slender, arranged radially. The skeleton in general is usually strongly radiate.

Tetilla O. Schmidt.

Typically the ectosome is not a distinct layer, but shades off into the choanosome; pores and oscula scattered and not located in special depressions. In some species, however, the ectosome is to some extent histologically differentiated and partially assumes the character of a fibrous cortex; and in some species there are special depressions on the floor of which the pores and oscula are located. There is no special cortical skeleton.

Tetilla laminaris, n. sp. (Pl. LVIII, fig. 14; Pl. LIX, fig. 17; Pl. LXVI, fig. 54*a* to *h*.)

Fairly abundant in Newport River in the vicinity of "Green Rock." The specimens used in preparing this paper were dredged at half tide, at a depth of 4 feet.

Sponge body (Pl. LVIII, fig. 14) a vertical lamella, elongated horizontally, the lower part of the lamella rooted in muddy sand by abundant fascicles. The lower edge of the lamella is thin; from this edge the body thickens gradually to the upper margin, which is rounded. The lamella is sometimes folded; the folds vertical. Sponge dense, firm. Color in the fresh state, grayish brown.

The root fascicles arise from the whole lower edge and the neighboring parts of the lateral surfaces; the uppermost, relatively high up on the lateral surface, are short; they increase in length toward the lower edge. In the collected specimens the length of the lower rootlets is for the most part 10 to 20 millimeters, but in one specimen the length reaches 50 millimeters. The rootlets are so abundant that the whole lower edge of the collected sponge bears, even after washing, a continuous mass of sand held in place by the root spicules. The rootlets were in large part removed from the specimen photographed.

In the type specimen the length is 115 millimeters, the greatest height 60 millimeters, greatest thickness 13 millimeters. Smaller and larger specimens are common. The largest specimen in the collection is 180 millimeters long, with a greatest height of 70 millimeters and greatest thickness of 30 millimeters. Relatively shorter and higher specimens occur, but the horizontal length is characteristically considerably greater than the height.

The surface of the upper part of the sponge body looks smooth to the eye. In reality, as may be seen with the lens, slender megascleres everywhere project from it for a fraction of a millimeter.

Numerous small oscula, 0.5 to 1.5 millimeters in diameter, the apertures of short oscular canals, are scattered along the upper margin at intervals, 2 to 15 millimeters apart. A few occur in some specimens on the lateral surfaces, near the upper margin. Pores about 30 to 60 μ in diameter abundantly scattered between the projecting brushes of spicules. They perforate the very thin dermal membrane and lead into small subdermal cavities which occupy an ectosomal zone about 60 to 80 μ thick. The intact surface appears dense to the eye; with a lens it is seen to be finely diversified by the minute subdermal cavities.

The ectosomal zone and the whole peripheral region to a thickness of about 0.5 millimeter is denser than the interior, owing to the smaller size of the canals; but, while the canals of the interior are numerous and larger than those of the ectosome, they are only a fraction of a millimeter in diameter (Pl. LIX, fig. 17). No part of the ectosome is differentiated to form a fibrous layer.

Skeletal framework.—The mesial region of the sponge lamella includes a number of spiculo-fibers which pursue, in the main, a vertical direction. From these, radial spiculo-fibers extend outward, terminating in a layer of closely set, peripheral, radial brushes, about 800 to 1,000 μ in radial length; the spicules of the brushes, projecting for the most part a short distance, about 100 μ; some of the protriænes three times as far (Pl. LIX, fig. 17). In the lower half of the sponge the radial spiculo-fibers pass obliquely downward. The rootlets are the prolongations of some of the radial fibers and of some of the lower mesial fibers. The spiculo-fibers are compact, cylindrical tracts in which the spicules are arranged longitudinally, without spongin. Between the fibers are scattered megascleres.

Spicules (Pl. LXVI, fig. 54*a* to *h*).—(1) Skeletal oxea, smooth, equi-ended, tapering gradually toward each end. There are two types which intergrade. The shorter form (fig. 54*a*) helps to make up the spiculo-fibers and is scattered between them. It is also abundant in the root fascicles. It is often slightly curved. Common sizes are 600 μ by 10 μ to 1,000 μ by 12 μ. A longer form (fig. 54*b*), with very slender extremities, generally straight or nearly so, with the ends sometimes curved or bent, is abundant in the spiculo-fibers. Common sizes are 1,500 μ by 16 μ to 2,300 μ by 20 μ.

(2) Oxea of the peripheral radial brushes (fig. 54*c*), inequi-ended, the outer end much the thicker; about 800 to 1,000 μ long, 8 μ thick near outer end, thence tapering gradually to inner end. In each brush there are several of these spicules.

(3) Protriænes of three types. Very slender protriænes, with hairlike cladi (fig. 54*g*); the most abundant spicule in the peripheral radial brush; rhabdome near outer end generally about 1 μ thick, 0.5 millimeter long; cladi much thinner, hairlike, 10 to 60 μ long; spicules projecting and covering whole surface of sponge, like fine hair. Immediately around an osculum these spicules are slightly larger than elsewhere, although the cladi are no thicker. Doubtless some of these spicules develop into the stouter forms of protriæne, but they can not be regarded as young stages of a characteristic skeletal element, for they themselves are a marked feature of the skeleton.

A stouter protriæne (fig. 54*e*) occurs in some abundance in the radial bundles of the lower half of the sponge, projecting from the surface; it occurs also, but rarely, in the upper part of body. Monæne and diæne modifications are present. Rhabdome 6 to 8 μ thick near outer end, tapering gradually and becoming very slender, about 2 millimeters long. Cladi fairly strong, 30 to 48 μ long, about 4 μ thick at base.

Immediately around an osculum abundant protriænes of the type shown in figure 54*f* occur, the spicules projecting in the usual way. Rhabdome at the outer end is about 3 μ thick, thence tapering gradually. Cladi about 2 μ thick at base, 14 to 40 μ long, commonly of unequal lengths, one cladus often considerably longer than the others. With these spicules are mingled the common, very slender forms (fig. 54*g*).

(4) Anatriænes of the ordinary character (fig. 54*d*) are abundant in the radial fibers of the lower half of the sponge, the entire spicule lying within the body; rhabdome about 6 μ thick near cladome, tapering gradually and becoming very slender, about 1,500 to 2,000 μ long; cladi about 32 μ long, strong, diverging less than 45 degrees from rhabdome. The root fascicles are largely made up of similar anatriænes, in which the rhabdome reaches a greater length, measuring in some isolated spicules as much as 3.5 millimeters.

(5) Sigmata, giving the common C and S shaped appearances (fig. 54*h*), are abundant in the ectosome, including that of the root fascicles, and in the walls of the canals. They are about 12 μ long. The surface of the spicule is slightly roughened, sometimes passing into a minutely spinose condition.

Hyatt has described and Sollas redescribed (Sollas, 1888, p. 46) a Tetilla, *T. gravata* Hyatt, from our Atlantic coast (Buzzards Bay), which is, however, a distinct species from the Beaufort form, although Hyatt's species perhaps extends southward as far as the North Carolina coast. At any rate, we have a number of specimens collected at Wrightsville, N. C., and Ocean View, Va., by R. Budd Chalmers, of Wilmington, N. C., which are certainly not far from *T. gravata*, possibly representing a variety. Unfortunately, all of our specimens are beach specimens, and the surface has been rubbed so that the spicular details necessary for a precise comparison can not be made out.

Discussion of the genus.—Recent writers are not in unison with regard to the use of this genus. Lendenfeld (1903) merges into it Chrotella Soll., and later (1906) merges Tetilla (+Chrotella) in Tethya (Craniella Soll.). Lendenfeld's action is based on the occurrence of intermediate forms, which make it impossible to divide this group of species clearly into the genera recognized in Sollas's scheme, which are based chiefly on the anatomico-histological features of the cortex. The intermediate forms unquestionably exist, but

Lendenfeld's treatment tends to obscure the nice distinctions to which Sollas's classification gives expression, and which should certainly not be lost sight of.

Topsent in 1904 continues to use the three genera, Chrotella, Tetilla, Craniella. Dendy in 1905 (p. 89) uses but redefines Tetilla so as to include forms in which the ectosome is in part fibrous. His definition runs: "Cortex absent or feebly developed; no special cortical skeleton." This is one way out of the difficulty presented by the occurrence of intermediate forms, in that Tetilla is here made to include species that shade off toward Tethya (Craniella), and which certainly are intermediate. To be sure, another classifier using the same genera might include such or slightly different intermediate forms under Tethya, extending Tethya downward, so to speak, rather than Tetilla upward. Dendy also uses Craniella in 1905, and again uses Tetilla in 1916, in the sense in which he employed it in 1905. Row in 1911 uses Tetilla and Chrotella. Hentschel in 1911 uses Tetilla, but in 1912 follows Lendenfeld and merges Tetilla (+Chrotella) in Tethya (Craniella auct.)

As exploration goes on the number of sponge genera known to run into one another increases. Everywhere intermediate forms are found. We meet, then, very frequently the practical difficulty of finding the record of a known species or of deciding where to record a new species. If the genera exhibited a linear arrangement, we might have sharply defined genera alternating with less homogenous intermediate ones. But it frequently happens that the species of a sponge family fall into groups which shade off in all directions toward one another. In such a case, and it looks as if discovery would show that this is all but universal in sponges, the questions arise: Shall we give up any formal grouping of the species (it is of course not a mere question of *names*, genera or subgenera)? Or shall we define all the species groups (genera or subgenera) in a comprehensive, and therefore rather loose, way, which results in overlapping? Or shall we meet the difficulty by accepting some sharply defined and other loosely defined genera? It is the latter method which is commonly employed, although not always explicitly, and no better treatment has as yet been found.

Tetilla, the simplest, and therefore presumably the ancestral genus of the family, has been gradually enlarged in the practice of recent writers (Dendy, Topsent, Hentschel) by the incorporation in it of species that depart in one direction or another from the central group of typical forms to which Sollas's definition is applicable. Topsent, for instance, includes (1904, p. 97) *T. longipilis*, in which there is the beginning of a cortex, viz, an ectosome which is in part fibrous; the species having differentiated in the direction of Tethya. Dendy (1905, p. 89) includes *T. hirsuta*, in which there are a more or less fibrous cortex and surface depressions, the smooth floor of which is perforated by pores or by oscula; a species with Tethya and Cinachyra-like features and which Lendenfeld (1903), in fact, lists as a Cinachyra. In the same paper (p. 91) Dendy includes *T. anomala*, in which the ectosome is pretty sharply differentiated from the choanosome, is fairly thick and to some extent fibrous, and "almost amounts to a cortex;" evidently a species approaching Tethya. Another species approaching Tethya has been more recently recorded by Dendy (1916, p. 105). This is *T. barodensis*, in which there is a well-developed dense cortex which is "perhaps to some extent fibrous." *T. cinachyroides* Hentsch. (1911, p. 283) and *T. limicola* Dendy (1905, p. 93) also deserve mention as intermediate forms; in the anatomy of the peripheral canal system, Cinachyra-like, although they lack the cortex of Cinachyra. Tetilla in this paper is accepted in the extended sense.

SIGMATOMONAXONELLIDA Dendy.

Family HAPLOSCLERIDÆ Topsent.

Microscleres often absent; when present never chelæ. The megascleres are usually diactinal. Where the skeleton is made up of distinct spiculo-fibers, these are typically not plumose.

Subfamily RENIERINÆ.

Megascleres oxeas or strongyles varying occasionally to styles. Skeleton reticulate, or the spicules may be scattered without definite arrangement. Spongin absent or present in small amount; only exceptionally does it envelop the spicules. No microscleres.

Reniera Nardo.

The skeleton is typically a close, uniform, reticulum, each side of the polygonal mesh formed by a single spicule. Spongin usually at the nodes of the reticulum. The side of the mesh may, however, be multispicular, and long multispicular fibers may develop.

Reniera tubifera, n. sp. (Pl. LVII, fig. 12; Pl. LVIII, fig. 15; Pl. LIX, fig. 16; Pl. LXVI, fig. 55*a*, *b*, *c*.)

Reniera sp., Wilson, 1910.

A fairly common species in the harbor. The best collecting locality is Newport River, close to the town. The sponge is scattered over the bottom and may conveniently be taken at low tide.

The body of the sponge (Pl. LVIII, fig. 15) is of irregular shape and consists of a reticular system of anastomosing cylindrical branches varying in diameter from 3 to 8 millimeters. It is not soft, but quite fragile. The specimen figured measures 130 millimeters in length, 30 millimeters in height. Rising vertically from the anastomosing branches are numerous tubes, 2 to 10 millimeters high and 1 to 3 millimeters in diameter, bearing oscula at their tips. In some cases these oscular tubes fuse with one another where they come in contact. The walls of the oscular tubes are colorless, thin, and transparent; the oscula at the tips measure 0.5 to 2 millimeters in diameter.

The dermal membrane of the sponge is delicate and is perforated by numerous irregularly distributed pores measuring about 50 μ in diameter. The pores open into small subdermal spaces, which ramify in the meshes of the ectosomal skeleton and lead into a system of very abundant canals in the sponge body (Pl. LIX, fig. 16). The flagellated chambers are conspicuous in stained sections and are very numerous. They measure about 25 μ in diameter. The mesenchyme is granular and rather scanty. Color of sponge pink or reddish purple, varying to brown; color fading quickly in alcohol.

Spicules (Pl. LXVI, fig. 55*a*, *b*, *c*).—Smooth, slightly curved oxeas measuring 125 to 170 μ by 3 to 8 μ, the smaller sizes, doubtless, being young stages. The usual variants occur in the shape of styles (fig. 54*b*) and strongyles (fig. 54*c*).

Skeletal framework (Pl. LVII, fig. 12, Pl. LIX, fig. 16).—The main skeleton (fig. 16) consists of a combination of fibers, reticulum, and scattered spicules. The fibers course longitudinally through the component branches of the sponge and are conspicuous. They are 30 to 100 μ in diameter, 3 to 8 spicules abreast, the spicules parallel to one another. In the parenchyma between the spiculo-fibers are many scattered spicules. These are commonly cemented together with spongin where they meet or cross, thus giving rise to a vague and irregular, predominantly unispicular reticulum. There are also many free spicules. The dermal and ectosomal skeleton (figs. 12, 16) is a distinct unispicular reticulum. The meshes are commonly three sided but may be four or five sided.

The Beaufort species departs from the typical Renieras, in which the skeleton is a unispicular reticulum, and falls in the large group of species in which special multispicular tracts are developed in the midst of a skeleton that preserves more or less the original character of a unispicular reticulum. (Vide Topsent, 1894*b*, p. 4; Dendy, 1894, p. 236.)

The following citations may help to put the Beaufort form in its proper place in the immense collection of Reniera species.

In *R. simulans* (Johnston) Schmidt there are multispicular primary skeletal lines (Topsent, 1901*a*, p. 356; Bowerbank, 1866, p. 308). The same is true in *R. dancoi* Tops. (Topsent, 1901*b*, p. 12). Among other species falling in this group may be mentioned *R. pigmentifera* Dendy (1905, p. 143), *R. massalis* Carter, and several other species recorded in Dendy's Catalogue (1894, pp. 236–238).

Where the habitus of the sponge is tubular the multispicular tracts may form *longitudinal* fibers curving outward toward the surface, connected by secondary tracts 1 or 2 spicules thick. This is the case in *R. scotti* Kirkpatrick (1908, p. 62), and is more or less true of *R. spinosella* Thiele, *R. implexa* Schmidt (Ridley and Dendy, 1887, p. 15; Topsent, 1904, p. 244), *R. utriculus* Tops. (1904, p. 246), *R. urceolus* Rathke and Vahl (Topsent, 1904, p. 246; Lundbeck, 1902, p. 35).

In several species the habitus is that of an erect lamella. In these forms also the multispicular tracts are longitudinally placed, and may be strongly developed, more especially in the basal part of the sponge. This is true of *R. parenchyma* Lundbeck (1902, p. 37), *R. folium* Lundbeck (1902, p. 39), *R. ventilabrum* Fristedt (Lundbeck, 1902, p. 40). In some forms of more or less massive habitus the multispicular tracts have no regularity of arrangement, e. g., *R. zoologica* Dendy (1905, p. 143).

Forms in which the skeleton is made up in part of a reticulum and in part of distinct polyspicular fibers might be referred, following Topsent (1904, p. 243), to Cladocroce Tops. The common practice (vide Lundbeck, 1902, p. 51) of not separating these species from the other less modified ones is followed, however, in this report.

In several forms the originally uniform skeletal reticulum is only retained at or near the surface, becoming looser and less distinctly developed in the interior. This is the case with the Beaufort species; with *R.* (*Isodictya*) *crassa* Bow., in which primary multispicular skeletal lines are developed (Bowerbank, 1882, p. 126); with one of the forms (Reniera species 8) recorded by Hentschel (1912, p. 411), in which this halichondrine tendency is not counterbalanced by the differentiation of distinct multispicular lines.

On the other hand, there are forms in which the original simple reticulum is supplanted in the ectosomal region by a reticulum composed of multispicular fibers. The original reticulum may persist at the very surface as in *R. semifibrosa* Dendy (1916, p. 112), or may here break up in halichondrine fashion into scattered spicules, as in *R. fibroreticulata* Dendy (1916 p. 111). In both of these species there are also internal multispicular fibers, and, as Dendy points out, a transition is made to Pachychalina.

Finally forms may be mentioned in which the skeletal reticulum departs from its primitive character in that all sides of all meshes become multispicular (Topsent, 1894*b*, p. 4).

Family DESMACIDONIDÆ.

The characteristic microscleres are cheloids (chelæ and modifications), but forms are included in which these spicules presumably have been lost during the course of evolution.

Subfamily MYCALINÆ.

Skeletal fibers, or spicular tracts, without echinating spicules and not markedly areniferous. The body has no fistular outgrowths.

Stylotella Lendenfeld.

Sponges of soft texture. Megascleres, styles in fibers or tracts and scattered. No microscleres.

Stylotella heliophila Wilson. (Pl. LVIII, fig. 13; Pl. LIX, figs. 18, 19; Pl. LXVI, fig. 53*a*, *b*, *c*.)

Stylotella heliophila Wilson, 1911, p. 13.

The most abundant sponge in Beaufort Harbor; common on the bottom in shallow water attached to shells, also under wharves attached to piles, stones, etc. Habitus varies. Sponge incrusts the shell or other substratum and grows up in the shape of lobes. These may be quite independent of one another. More commonly the ascending lobes fuse where they touch, and thus a more compact mass is produced, reaching, but rarely exceeding, 100 millimeters in diameter. The surface is roughened by minute conulose elevations ½ to 1 millimeter high. Color orange, sometimes with a greenish cast. A typical specimen is shown in Plate LVIII, figure 13.

The oscula are mostly located at the ends of the vertical lobes and at the ends of tapering, more or less conical, outgrowths from the lobes. The pores, which in an alcoholic specimen measured from 20 to 45 μ in diameter, are irregularly scattered in great abundance over the dermal membrane. The dermal membrane (Pl. LIX, fig. 18) is translucent. Beneath it may be seen a richly developed system of conspicuous subdermal canals 3 to 4 millimeters and less in diameter.

Spicules (Pl. LXVI, fig. 53*a*, *b*, *c*).—The only spicules present are smooth styles, slightly curved or sometimes straight. The range of size is 120 to 350 μ by 4 to 9 μ. In addition, there are present some very slender styles measuring 115 to 225 μ by 2 μ or less. These are scattered in the parenchyma and are doubtless young stages of the skeletal spicule.

Skeletal framework (Pl. LIX, figs. 18, 19).—The spicules of the interior are irregularly scattered. Here and there they cross one another so as to give rise to meshes, or they may combine to form spiculo-fibers or tracts (fig. 19). A small amount of spongin is present in the spiculo-fibers and at some of the points where the spicules cross. The spicular tracts are commonly present in the trabeculæ between the larger canals. They often fray out in a brush-like fashion at the surface. In the ectosome are abundant, more or less radially arranged styles, some slightly projecting.

In the dermal membrane the styles very generally project more or less radially, frequently forming the dense brush-like groups referred to above, but between these they are scattered more or less tangentially (fig. 18).

Stylotella Lendenfeld was diagnosed by its author (1888, p. 185) as follows: "Heterorrhaphidæ of very soft texture. Megasclera styli, in bundles and scattered. No microsclera." Dendy (1896, p. 231) deletes the genus as not distinguishable from Hymeniacidon Bowerbank, which he places in the Axinellidæ. Topsent (1899, p. 109) retains the genus and thinks its relationship is with Esperella (Mycale). He gives the following diagnosis: "Esperellinæ with reticular skeleton. Fibers (at least the primary ones) multispicular. Megascleres: styles. No microscleres." Lindgren (1898, p. 313) follows Dendy, merging the genus in Hymeniacidon. Kirkpatrick (1900, p. 137) retains the genus. Topsent (1904, p. 224) criticises Dendy's treatment of the genus and retains it, placing it in the Esperellinæ. Dendy (1905, p. 185) again records his opinion that the genus is not distinguishable from Hymeniacidon, which he continues to place in the Axinellidæ. Hentschel (1912, p. 355) retains the genus and follows Topsent in placing it in subfamliy Mycalinæ (Esperellinæ auct.) in the Desmacidonidæ (= Poeciloscleridæ Tops.). It seems to the writers that Topsent's treatment is the correct one.

Esperiopsis Carter.

Habitus varies; incrusting, amorphous, and more or less upright forms occur; the latter may be leaflike or subcylindrical and branching. Spongin commonly present, the amount varying. Skeleton varies from a state in which there are well-developed spiculo-fibers, with abundant spongin, to a renierine or halichondrine condition. Megascleres, styles, some of which may undergo the strongylate modification, often with tylostyles. Microscleres, isochelæ, which may be accompanied by stigmata, toxæ, or forcipes.

Esperiopsis obliqua n. sp. (Pl. LX, figs. 20 to 23; Pl. LXVI, fig. 58*a*, *b*, *c*, *d*, *e*, *f*.)

Five specimens; three collected on Fort Macon beach; one dredged just outside Beaufort Inlet; one dredged on the "Fishing Bank" off the inlet.

Sponge is ramose; the branches cylindrical or subcylindrical, smooth or knotty, sometimes distinctly compressed, commonly 4 to 6 millimeters in diameter. The main branches arise from a base and themselves branch. Fusion takes place sometimes between contiguous branches. Sponge may be vertical, or the branches may extend out in various directions from the base. The upright specimens range in height from 60 to 200 millimeters. A specimen with spreading branches has a greatest diameter of 50 millimeters. Sponge firm, but compressible and elastic. Color bright red.

The known specimens show three fairly distinct types of habitus. But as no definable skeletal peculiarities are associated with these differences of the exterior, the types are, doubtless, only individual forms, reached as a result of particular growth and differentiation responses that are called out by the local environment. In one type (Pl. LX, fig. 21) the habitus is chaliniform. The branches, in general, are long, slender, cylindrical, smooth, and taper terminally. In one of the two specimens of this type a few lobes are slightly knotty here and there. In a second type (Pl. LX, fig. 20) the distinguishing features are the knotty character of the branches and the biseriate arrangement of the oscula. In a third type the branches are smooth but enlarged terminally, clavate or spatulate. This type is represented by the specimen with spreading branches and less well by a small specimen 60 millimeters high, which, perhaps, was vertical.

Dermal membrane thin, perforated everywhere with pores which lie in the meshes of the dermal skeletal reticulum. Actual diameter of pores in preserved specimens varying, often 20 to 50 μ. Dermal surface shows to the eye or lens the outer ends of small cylindrical afferent canals which pass radially inward; these appear as circular areas, mostly 175 to 300 μ in diameter, abundantly scattered over the surface and covered in by the thin dermal membrane. The area of membrane covering in such a canal usually shows about three pores.

Oscula small, 1 millimeter and less in diameter, scattered without order or arranged more or less definitely in longitudinal rows, which may be biseriate, viz, two rows on each branch opposite one another. In the larger chaliniform specimen (Pl. LX, fig. 21) only one branch shows anything of this regularity in the location of oscula. On this branch a biseriate arrangement appears, but it is vague; that is, irregular. In another specimen of the chaliniform type and in one of the clavate-spatulate type the oscula are arranged in short, irregular, longitudinal rows, but a biseriate arrangement is not present. In the specimen with knotty branches (Pl. LX, fig. 20) the biseriate arrangement is distinctly developed on almost all the branches, the oscula of a row lying 1 to 5 millimeters apart.

Embedded in the tissue of one of the specimens are numerous embryos containing many immature spicules. A good many sand grains and some large, broken, foreign monaxon spicules are embedded in the outer part of the body in the case of several specimens.

Spicules (Pl. LXVI, fig. 58*a*, *b*, *c*, *d*, *e*, *f*).—Megascleres: (1) Style, the chief megasclere, slightly curved, tapering toward base as well as toward point, generally smooth but sometimes spinulate, characteristically 110 to 150 μ by 6 to 10 μ. Slenderer ones appear, especially in the connectives. The spinulation may be limited to the head, or small spines may be present over a part or a whole of the shaft. (2) Strongyle, of about same size as the style but much less abundant; obviously a modification of it. (3) Ectosomal tylostyle, commonly straight, slender, and cylindrical, sharp-pointed, head slightly tylote, 120 to 140 μ x 2 μ. Present but not at all abundant in the ectosome, where it is placed radially or obliquely, usually projecting. Microscleres: (4) Isochela with twisted axis, 9 to 11 μ long; fairly abundant in the parenchyma; very abundant in spots in some specimens. When one tooth is seen in ventral view the other appears more or less in side view. Occasionally the rotation is greater, and both teeth are seen flatwise, one in ventral, one in dorsal, view. Normal chelæ, in which the axis is not twisted, also occur, but very rarely. The spicules are small and delicate, requiring to be studied with an immersion objective. In a foreshortened view the terminations appear as more or less circular cups on opposite sides of the apparently short axis. (5) Toxa, 20 to 60 μ long, in parenchyma, less abundant than the chela.

Skeletal framework (Pl. LX, figs. 22, 23).—Principal fibers and connectives are distinguishable. The former are primarily longitudinal, branching as they ascend, the branches curving out radially toward the surface. These fibers are polyspicular; the spicules arranged lengthwise or somewhat obliquely, and for the most part completely embedded in spongin. A few spicules project here and there at right angles to the fiber, doubtless representing connectives that will develop.

The longitudinal fibers are about 30 to 60 μ thick. They include 3 to 8 lines of spicules as seen in optical longitudinal section of the fiber. Transverse sections show that the actual number of lines of spicules ranges in different specimens from about 3 to as many as 20. The radial parts of the fibers have usually 2 to 4 lines of spicules.

The connectives are mostly one spicule in length, sometimes two, and at about right angles to the principal (longitudinal or radial) fibers. They include 1 to 2 rows of spicules, sometimes as many as three rows, when all or all but one row are quite slender. The spicules are well covered with spongin. Meshes often longer than wide, rectangular; or squarish. While the style is the chief skeletal spicule, the strongyle is very common in the connectives and perhaps predominates in them.

In the ectosomal region, including a thickness of about 350 μ, the principal fibers are somewhat closer together than in the interior, and there are more connectives (Pl. LX, fig. 22). The skeleton is thus denser in this region. The radial fibers project slightly beyond the surface of the sponge, the terminal spicules diverging and projecting beyond the spongin of the fiber.

The dermal membrane is supported by the most superficial connectives, which extend between the outer ends of the radial fibers. These dermal connectives have the usual character; that is, they commonly have the length of one spicule, sometimes of two; the included spicules, one or two rows, are entirely embedded in the abundant spongin; common thickness of connective, 12 to 16 μ; mesh squarish or polygonal. Here and there a spicule with its base rooted in the connective projects, at right angles to the latter, beyond the surface of the sponge.

There is considerable quantitative variation both in the skeletal framework and the megascleres. Thus, in the same specimen the framework is somewhat denser in the older than in the uppermost part of a branch, owing largely to the fact that the connectives are more numerous and, perhaps, somewhat thicker. The differences between the several specimens in respect to these points are noticeable, although vague. In those of the chaliniform type (Pl. LX, fig. 21) the principal fibers are slenderer and the skeletal styles perhaps slenderer than in the other specimens. Thus, in one of the chaliniform specimens the range in the actual number of rows of spicules contained in the longitudinal fibers is about 3 to 8, whereas in the biseriate specimen (Pl. LX, fig. 20) it is 4 to 20. In one of the clavate-spatulate specimens the skeletal style is very often noticeably stout and fusiform. But these stout styles are accompanied by a great many quite slender ones.

The Beaufort sponge is not far from *Esperiopsis anomala* R. and D. (Ridley and Dendy, 1887, p. 84), a ramose sponge from Honolulu, in which there is a rich development of spongin, producing a chalinine appearance. Ridley and Dendy remark on this fact that it "forms a very good instance of the manner in which horny fiber may be developed in any genus." Other species of Esperiopsis in which horny fiber is extensively developed are *E. symmetrica* R. and D. from off Port Jackson (Ridley and Dendy, 1887, p. 79), *E.* (*Amphilectus*) *hispidula* (Ridley) from Torres Strait (Ridley, 1884,

p. 429), *E. rigida* Lambe from the Pacific coast of Canada (Lambe, 1893, p. 68). In many species of the genus the fibers consist chiefly of spicules, with comparatively little spongin.

The parallelism in habitus and skeletal framework between species of Esperiopsis, Homœodictya, and Pachychalina is noteworthy. Lundbeck has remarked (1905, p. 122) on the close parallelism between *Homœodictya palmata* Johnson and a species of Pachychalina. The parallelism is equally close with *E. obliqua*.

A similarity of another kind, involving the fundamental matter of spicule combination, is presented by Esperiopsis species in general to Artemesina Vosm. This similarity is perhaps not a case of parallelism, but one due to close kinship. And in this connection it may be recalled that Topsent (1904, p. 215) described a species of Artemesina in which the texture of the body differs notably from that of *A. suberitoides* Vosmaer, etc., approaching that of Esperiopsis. Topsent suggests that it might be well to make Artemesina a subgenus of Esperiopsis, to include forms in which the body has a texture like that of Suberites.

The peculiar isochelæ of the Beaufort species deserve a word. They look quite like those of *Microciona acerato-obtusa* Carter, as drawn by Hentschel (1911, p. 349). Very small isochelæ, but not twisted, are recorded by Dendy (1895, p. 18) for *Esperiopsis turbo* (Carter); Dendy says they are very minute and difficult to detect.

The occurrence of twisted chelæ (aniso-and iso-chelæ) is regarded by Vosmaer as evidence, over and above the embryological, in favor of the idea that the chela is derived from the sigma (1902, p. 9). This is at least defensible, for the twisting of the chela is in itself a structural feature that is sigmalike; that is, the twisted chela is intermediate, in respect to the shape of the spicular axis, between the sigma and the normal chela, although in other respects it is a perfectly differentiated chela. It, then, in some small measure, controverts Hentschel's position that there are no intermediate forms between chela and sigma (1914, p. 158). Nevertheless, the spicule is "intermediate" in respect to a single point only, and this makes it very doubtful whether the point (of resemblance) is really to be looked on as a case of reversion. It is perhaps a quite new acquisition, which happens to coincide with a phylogenetically older state. Lundbeck (1905, p. 6) thinks "the fact that chelæ may be contort, a feature that is much more frequent, and may take place to a much higher degree than seems to be known by the authors, proves nothing at all" in respect to the phylogeny of the chela.

Lissodendoryx Topsent (emend. Lundbeck 1905).

Skeletal framework reticular, including sometimes well-marked fibers, or dendritic; spongin present more or less abundantly. Skeletal megascleres generally smooth styles, but sometimes spined; dermal megascleres diactinal. Microscleres isochelæ, never ancoræ, to which sigmata may be added.

Lissodendoryx carolinensis Wilson. (Pl. LXI, figs. 26, 27, 28; Pl. LXVI, fig. 62*a*, *b*, *c*, *d*, *e*.)

Lissodendoryx carolinensis Wilson, 1911, p. 11.

Common in the harbor, especially on the wharf piles; best collecting places, Gallant's Point, oyster cannery in Newport River, Morehead pier.

The sponge begins as an incrustation on shells, etc. As it grows ascending lobes, frequently overlapping, develop. Eventually a large amorphous mass may be produced, the body of which has been formed by the continued fusion of such lobes. The free surfaces of such masses continue to bear projecting lobes like those of the younger stages. A characteristic specimen (Pl. LXI, fig. 26) measured 100 millimeters in its greatest diameter. Masses with diameter twice as great occur.

Color white, frequently with a green or blue cast. Sponge comparatively firm and brittle, and generally dirty. It is much infested with worm tubes and overgrown with hydroids and polyzoa.

Over the entire surface are numerous tubular translucent papillæ (Pl. LXI, fig. 27), perforated by numerous pores. The papillæ may be simple or branched, often bifurcated. They are contractile and may almost entirely disappear.

Oscula 1 to 2 millimeters in diameter are scattered over the surface and often develop at or near the ends of lobes. The pores are distributed over the general dermal membrane and papillæ. Over the papillæ they are abundant and in an alcoholic specimen measure about 20 μ in diameter. In the same specimen the pores over the general surface are almost all closed. The few found open measure up to 100 μ in diameter. The dermal membrane is translucent, showing anastomosing subdermal canals, commonly about 0.5 to 0.75 millimeter wide.

Spicules (Pl. LXVI, fig. 62*a*, *b*, *c*, *d*, *e*).—Megascleres: (1) Style, smooth and slightly curved. Range of size, 160 to 180 μ by 5 to 8 μ. (2) Tylote, smooth. Range of size, 160 to 190 μ by 5 μ. Microscleres: (3) Isochelæ arcuatæ 12 to 26 μ long. (4) Sigmata 18 to 36 μ long.

Skeletal framework (Pl. LXVI, figs. 27, 28).—Internal skeletal framework is a loose, irregular reticulum formed by styles, which may in places develop into spiculo-fibers. Meshes of reticulum are three to five sided; side of mesh about the length of a spicule, formed by one, two, or three spicules. Spongin present at the nodes (stained sections show it). In addition to the skeletal reticulum, the parenchyma contains some scattered tylotes. These may be grouped to form loose tracts. The tylotes are especially abundant in collenchymatous regions, and are more abundant in the ectosome than elsewhere.

The megascleres of the dermal membrane are tylotes. In places they are scattered tangentially in the membrane, but very generally they project more or less radially, forming bunches or ridges. The wall of the papilla (Pl. LXI, fig. 26) is an extension of the dermal membrane, and the megascleres here, too, are tylotes, tangentially arranged and forming a reticulum, in the meshes of which are the pores.

The whole parenchyma is loaded with sigmata; isochelæ abundant, but less abundant than the sigmata. Both sigmata and isochelæ are abundant in the general dermal membrane. The wall of the papillæ contains moderately abundant isochelæ and very few sigmata.

Topsent established Lissodendoryx first as a subgenus of Dendoryx (1892) and later (1894*a*, p. 9) as a separate genus, for species which differ from Dendoryx (=Myxilla *sens. str.*, Thiele, 1903; Lundbeck, 1905; Topsent, 1913) in having smooth styles as the skeletal megascleres.

Dendy (1895, p. 29) would include the genus, and Dendoryx as well, under Myxilla, Schmidt. Topsent (1901*b*, p. 19; 1904, p. 173) retains the genus as originally defined.

Lundbeck (1905, p. 153) again brings up Dendy's contention (1895) that the smoothness of the styles can not be used as a generic character, since species occur with styles that are intermediate between spined and smooth ones. From this point of view the genus should be merged in Dendoryx (=Myxilla *sens. str.*). But the Dendoryx species, Lundbeck maintains, are separable into two groups, in one of which the microscleres are ancoræ, in the other chelæ arcuatæ. For the former Lundbeck reserves the name of Myxilla (*sens. str.*, Topsent, 1913, p. 623), for the latter Lissodendoryx.

Subfamily PHLŒODICTYINÆ.

Sponge body provided with fistular outgrowths. Characteristically the ectosomal skeleton is much denser than the choanosomal, constituting a sort of rind. The microscleres are often absent.

Phlœodictyon Carter.

Spongin usually present, but the skeleton is not a reticulum of distinctly chalinine spiculo-fiber. Megascleres, oxeas varying to strongyles. There are no microscleres.

Phlœodictyon nodosum n. sp. (Pl. LXII, figs. 29, 30, 32; Pl. LXVI, fig. 63.)

One specimen dredged in Beaufort Harbor.

Slender fistulæ, 30 to 35 millimeters high and 1.5 to 3 millimeters in diameter, rounded off and closed terminally, connect with a basal portion which is attached to a piece of shell. The basal portion is incomplete. As it stands it consists of an incrusting part on the upper surface and a somewhat thicker, 2 to 3 millimeters thick, torn part on the under surface of the shell. The entire sponge was probably not large. The shell is probably to be looked on as having been surrounded by, and incorporated in, the upper part of the sponge body.

Color, in alcohol, whitish brown. Wall of fistulæ thin, but firm. Many sand grains and pieces of shell have been incorporated by the sponge.

The dermal membrane of the fistular wall is perforated by pores lying in the meshes of the skeletal reticulum. Many of the pores are closed, and those that are not closed are probably only partly open. They measure 12 to 16 μ in diameter. The membrane is thin, contains only a few granular amœbocytes, and is favorable for histological study. Some few foreign incrustations cling to it, among them holothurian (synaptid) spicules such as Bowerbank has figured (1864, Pl. V, figs. 119, 120).

Pores and oscula over basal part of sponge uncertain. This part exhibits a good many small canals, 120 to 500 μ in diameter. Flagellated chambers spheroidal, or about so, 28 μ in diameter. The ectosome of the fistular wall includes a great many small, rounded subdermal cavities, about 60 to 100 μ in diameter as seen in cross sections of the fistula (Pl. LXII, fig. 30). Internal to the ectosomal skeleton, the fistula is collenchymatous and is excavated by a large axial canal around which lie smaller canals, which yet are of good size, about 150 to 350 μ in diameter (fig. 30). These are separated by thin sheets and strands of sponge tissue.

All the fistulæ are closed terminally, showing no sign of oscula. If ordinary oscula were present in life, one would expect to see some sign of them in the preserved specimen. Perhaps the axial canal opens terminally through a sieve plate, the apertures of which, resembling pores, are now closed. As Lundbeck says (1902, p. 58), there is diversity of opinion with regard to the functioning of the fistulæ in these sponges. Living, or, at any rate, carefully preserved whole specimens need to be studied. The pores over the general surface and the subdermal cavities of the ectosome make it clear that water streams into the fistula. Nevertheless, perhaps the axial canal is efferent. It would seem that it must be so in species such as *P. elongatum* Tops., where it connects with the exterior by a terminal or subterminal aperture which has the appearance of being normal (Lundbeck, loc. cit., p. 60).

Spicules.—Oxeas (Pl. LXVI, fig. 63) smooth, slender, slightly curved, subcylindrical, tapering gradually to sharp points, about 100 μ by 4 to 5 μ. The strongylate modification occurs.

Skeletal framework of the fistulæ.—The ectosomal skeleton includes the usual parts, a dermal layer of tangential spicules and a subjacent layer of spiculo-fiber.

The dermal spicules intercross in all directions, constituting a layer which is, in general, single, although in places parts of two or three spicules may be superposed. The spicules form a reticulum (Pl. LXII, fig. 32), at the nodal points of which they are held in place by spongin. These nodal points in a stained preparation of the wall are conspicuous. Meshes of the reticulum triangular or polygonal; side of a mesh the length of a spicule or less and formed by one, or, in places where the spicules are more abundant, by several, about two to five, spicules. In regions of the latter character the spicules are so closely grouped that they radiate from many of the nodal points, like spokes of a wheel. Elsewhere in the same fistula the reticulum may be unispicular.

Beneath the dermal layer of the fistula and about a spicule's length from it lies the fibrous layer. The two are connected by small bundles of spicules or by single spicules, which extend radially or obliquely to the surface between the subdermal spaces (fig. 30).

The fibrous layer consists of polyspicular spiculo-fibers (figs. 30 and 32), which pursue a longitudinal course, dividing and anastomosing to some extent, interconnected by slender tracts of spicules or by scattered spicules forming a secondary reticulum. The secondary reticulum varies in character in the same fistula. The mesh may be polygonal, with a side equal to the length of a spicule, unispicular in one region, polyspicular in another; or the spicules may be thickly and confusedly crossed, giving the mesh a side less than the length of a spicule; or the mesh may still be polygonal, but its sides two or three times the length of a spicule and formed by polyspicular tracts. At the nodal points of the reticulum there is spongin. The main longitudinal fibers are 30 to 80 μ thick; spicules of a fiber arranged lengthwise, closely packed, and bound together by a very small amount of spongin, which does not form a covering for the fiber.

Internal to the fibrous layer the fistular wall contains almost no skeleton. At most a few spicules project radially and obliquely inward from the fibrous layer, and here and there a free spicule is found.

Skeletal framework of basal part of sponge.—Where the surface of this part of the sponge has been preserved, an ectosomal skeleton is found much like, nevertheless somewhat different from, that of the fistula. There is a dermal layer, two or three spicules thick, of tangential megascleres, which cross in every direction. These are united, as in the fistular wall, by spongin at the nodal points, but the spicules are so abundant that they can not be said to form a reticulum. Still they are not as densely packed as in some species; everywhere minute angular spaces, commonly about 12 μ in diameter, are left between them.

Beneath the dermal layer and visible through it spiculo-fibers, like those of the fistula, form a coarse and very irregular reticulum.

The choanosomal skeleton consists chiefly of abundant scattered single spicules, crossing one another in all directions, without spongin. Here and there the spicules are combined to form loose tracts.

The Beaufort species is nearest *P. reticulatum* Tops. from the Azores (1904, p. 238). But in the latter the spicules of the dermal layer are loosely intercrossed; the fibrous layer of the ectosome is a network with subequal, round, or oval meshes; and the oxeas are larger, 175 to 210 μ by 3 to 13 μ.

Lundbeck (1902, p. 56) dissolves Carter's group Phlœodictyinæ and distributes the genera (Rhizochalina, Phlœodictyon, and Oceanapia) among the Chalininæ, Renierinæ, and Gelliinæ. The treatment is logical if we regard only the spicules (and, in the case of Rhizochalina, the character of the spiculo-fiber). Topsent (1904) and others have followed Lundbeck. Dendy (1905), keeping in mind the presence of fistulæ and the dense ectosomal skeleton, constituting a rind, retains the group, adding to it Histoderma, Sideroderma, and Amphiastrella, which necessitates placing it in the Desmacidonidæ. The group, as Dendy remarks, seems to be a natural one.

Subfamily PHORIOSPONGINÆ Lendenfeld, 1888, 1889, emend.

The skeletal fibers are very areniferous, sometimes partly spicular; they may be reduced to rows of sand grains united or not by spongin. Skeleton usually reticulate, but sometimes consisting of independent fibers or of scattered sand grains. The megascleres are monaxonid, monactinal or diactinal, or both. The microscleres are chelæ and sigmata, but either or both may be lacking. The flagellated chambers are (always?) eurypylous and large.

Phoriospongia Marshall, emend.

[With the characters of the subfamily.]

Phoriospongia, Marshall, 1880.
Chondropsis (Sigmatella Lendenfeld), Dendy, 1894.
Psammochela, Dendy, 1916.

Phoriospongia osburnensis, n. sp. (Pl. LXI, figs. 24, 25; Pl. LXVI, fig. 60*a*, *b*, *c*.)

A single specimen (Pl. LXI, fig. 24) taken on the "Fishing Bank" off Beaufort Inlet by Dr. R. C. Osburn at a depth of 13 fathoms.

Sponge forms a thin incrustation over an alcyonarian coral. It is for the most part about 1 millimeter thick, thinner in places, and twice that thickness in some spots.

Color whitish in alcohol, on the salmon-pink alcyonarian. Oral ends of the alcyonarian polyps in general free of the incrustation. Loxosoma is scattered in abundance over the surface of the sponge.

Surface fairly smooth. Pores 50 to 80 μ in diameter, abundantly scattered over the dermal membrane, which is quite riddled with them in many places, probably everywhere when they are open. Small, rounded subdermal cavities, mostly 125 to 250 μ wide, are very abundant and give to the surface of the sponge, when examined with a lens, a porous appearance. Oscula uncertain; probably small and scattered, and now closed. Many canals, the largest about 200 μ wide, excavate the parenchyma, some passing radially through the incrustation from the surface almost to the base. Flagellated chambers uncertain. Abundant, small, compact cellular masses, doubtless embryos, occur in the parenchyma.

Spicules (Pl. LXVI, fig. 60*a*, *b*, *c*).—Megascleres: (1) Strongyles, subcylindrical with bluntly rounded ends, slender, smooth; about straight or slightly curved; 160 to 180 μ by 2 to 3 μ. Microscleres: (2) Sigmata, 10 to 20 μ long; the common and characteristic length, 14 to 16 μ. Abundant in dermal membrane; scantily present in the interior, canal walls, and parenchyma. (3) Isochelæ, 12 to 16 μ long; very scantily present in dermal membrane and interior. The axis is distinctly curved and the spicule is tridentate, the toothed end about one-fourth the total length. The teeth appear, under a good immersion objective, elongate-conical, but the small size of the spicule makes minute details somewhat uncertain. The spicule probably falls in the Levinsen-Lundbeck (Lundbeck, 1905, p. 2) class of chelæ arcuatæ; that is, there is at each end only one tooth proper, the lateral "teeth" being the alæ, which are separated by deep bays from the shaft. These spicules were at first overlooked in the sponge, but after their discovery search revealed a few in every preparation.

Skeletal framework (Pl. LXI, fig. 25).—There is no reticulum. Instead, simple, unbranched, skeletal fibers pass more or less radially from the base of the sponge to the surface (fig. 25). They often curve a good deal, and the precise direction of the fiber frequently corresponds with that of an adjacent large canal; obviously a case of correlation. The fibers are made up of sand grains, with which some bits of foraminifer shells or pieces of foreign sponge spicules are intermingled, proper spicules (strongyles) of the sponge, and spongin.

The sand grains of the fiber and bits of shell, etc., are frequently but not always arranged in a single series. The grains may be all small, or here and there a much larger one is intercalated. Covering them sparingly are strongyles, arranged more or less lengthwise in the fiber. There are short parts of many fibers in which no sand grains are present; these are composed of compact tracts of longitudinally placed strongyles. The spongin of the fiber is scanty. Yet there is enough not only to connect but to form a thin covering over the mineral elements of the fiber. It is very transparent and easily overlooked.

The skeletal fibers in the ectosomal region are frequently made up chiefly of proper spicules, strongyles, which at the surface project slightly, often diverging. Beside these radial or obliquely radial bunches, free megascleres occur here and there in the ectosome, inclined more or less radially to the surface. The skeletal fibers, owing to their composition, vary greatly in thickness, even within the same fiber. Parts of fibers may be only 20 μ thick, other parts 160 μ thick. The fibers are abundant, frequently 175 to 350 μ apart. Between the skeletal fibers there are, in the body of the sponge, some scattered megascleres.

The dermal membrane contains a good many strongyles lying tangentially, scattered singly or in wisps; also the projecting tufts of spicules, above referred to, which represent the upper ends of skeletal fibers. Flat preparations seem sometimes to show skeletal fibers running tangentially in the dermal membrane. But sections prove there are no such fibers, and that the appearance is caused by fibers which run from base to surface as usual, but very obliquely and in regions where the sponge is quite thin.

We had at first decided to inscribe this sponge under Dendy's recent genus Psammochela, the diagnosis (Dendy, 1916, p. 126) of which reads: "Reticulate skeleton composed of sandy and sometimes partly spicular fibers. Magascleres styli or strongyla, or both. Microscleres isochelæ, which may be very minute and with vestigial teeth; to which sigmata may be added." But we now feel, for the following reasons, that the subdivision of the Phoriosponginæ into Phoriospongia, Chondropsis, and Psammochela is not satisfactory.

The distinction between Phoriospongia and Chondropsis (Sigmatella) is arbitrary. Lendenfeld (1888, 1889) based the distinction especially on the sigmata. Forms with large sigmata, 30 to 50 μ long, were put in Phoriospongia, those with very small sigmata, 5 to 10 μ long (Lendenfeld's figure indicates that the 1 μ given in the text as the length of the sigma in *Chondropsis australis* is a misprint for 10 μ. Vide Lendenfeld, 1889, p. 611.), or with none, in Chondropsis (Sigmatella).

Dendy (1894, p. 250) found it necessary to change Sigmatella (preoccupied) to Chondropsis, and further pointed out that the size of the sigmata could not justly be used as a mark by which to distribute the species of the subfamily. In recorded species the sigmata measure 5 μ, 10 μ, 16 μ, 30 μ, 35 μ, 50 μ in length, thus forming a fairly continuous series. Dendy nevertheless retains the two generic names Phoriospongia and Chondropsis, and would assign to the former species with monactinal megascleres, and to the latter those with diactinal megascleres. Hence, several forms listed by Lendenfeld under Phoriospongia are shifted by Dendy to Chondropsis.

But Dendy's basis for the distinction between the two genera can not be thought of as satisfactory since the character of the magascleres is variable in these sponges, as is borne out by the following: Lendenfeld (1889) records that the megascleres in *Chondropsis* (*Sigmatella*) *australis* are chiefly strongyles but in part styles and tylotes; in *C. turbo* they are strongyles with some styles; in *C. corticata* strongyles but also in part oxeas and styles. In Dendy's new addition to the subfamily, Psammochela (Dendy, 1916, p. 126), the megascleres are styles or strongyles or both. It seems therefore necessary to merge Chondropsis into Phoriospongia.

As to Psammochela, its distinction from Phoriospongia rests on the presence of chelæ. It does not seem justifiable, however, to separate from Phoriospongia forms like the Beaufort species in which the chelæ are so scarce as to be easily overlooked. Rather we may conclude with a good deal of probability that actual search will reveal a scanty number of chelæ in some, at any rate, of the forms hitherto listed under Phoriospongia and Chondropsis and supposed to be without these spicules. Further, it may be recalled that in one of the specimens of Ridley's *Phoriospongia fibrosa* (Ridley, 1884, p. 439) chelæ were found to be scarce, in the other abundant. This indicates that it is not rational to separate the forms with abundant chelæ from those with few or none.

Phoriospongia should therefore be emended to include forms both with monactinal and diactinal megascleres, and those in which chelæ persist either abundantly or in small number. It thus becomes coextensive with the subfamily, and some artificial grouping of the species may be desirable as facilitating reference to them.

As to the position of the genus, Lendenfeld (1888, 1889) made his Phoriosponginæ a subfamily of the Spongelidæ. Dendy (1894, p. 250) and Topsent (1894*b*, p. 5) transferred the genera to the Monaxonida, placing them near their supposedly closest relatives, the Gellius-like sponges. Dendy more recently (1916, p. 126) utilizing the data afforded by his *P.* (*Psammochela*) *elegans*, has shown that the sponges belong in the Desmacidonidæ, although the chelæ have apparently been lost by many species.

The species of this subfamily, except the Beaufort form, are all known to reach a large or, at any rate, a good size. Tubular and flabelliform shapes and a massive or irregular form of body with processes are common. At least three species are known in an incrusting phase, *P.* (*Sigmatella*) *corticata papillosa* (Lendenfeld, 1889, p. 620), *P.* (*Sigmatella*) *carcinophila* on crabs (Lendenfeld, loc cit., p. 615), and *P.* (*Desmacidon*) *psammodes* (Hentschel, 1911, p. 322; Dendy, 1916, p. 126). Perhaps the Beaufort species will be found in some larger phase. That it breeds in the thin, incrusting condition is no reason for believing that this is its final state. *Microciona prolifera*, for example, breeds in Beaufort Harbor, while a thin incrustation having a skeletal arrangement much like that of *P: osburnensis* (Wilson, 1911, Pl. I, fig. 5); but, while the great majority of individuals in the harbor do not get beyond an incrusting condition, much larger and more complicated phases are reached by some. If *P. osburnensis* reaches a large size, probably its skeleton becomes reticulate. At present it is the only recorded form, except *P. solida* Marshall, which lacks recognizable fibers, in which the skeleton is not reticulate, although in *P.* (*Sigmatella*) *carcinophila* Lendenfeld (1889, p. 615) the reticulum is confined to the basal portion of the sponge, while from it isolated vertical fibers pass to the surface.

The complete loss of spongin in some forms, if it really occurs, is a remarkable fact, especially since the skeletal sand grains continue to be arranged by the sponge in bands. Perhaps the spongin is really not absent in these forms but only very scanty and transparent. Ridley (1884, p. 439) says that in *P. fibrosa* the skeletal "fibers are wholly composed of foreign bodies united by an almost colorless, not dense, substance," and, as stated above, the spongin in *P. osburnensis* is easily overlooked.

The species of the subfamily hitherto recorded are all from Australian waters. Two of the forms are, however, thought by Lendenfeld (1889, pp. 613, 620) to occur elsewhere, *P.* (*Sigmatella*) *australis var. tubaria* at Nassau (Bahamas) and *P.* (*Sigmatella*) *corticata var. papillosa* on the English coast, African coast, in the Indian Ocean, and on the Florida coast. The last-named item of distribution rests on the identification of Hyatt's *Spongelia kirkii* (Hyatt, 1877, p. 539) as a *Phoriospongia* (*Sigmatella*), but I can not find that Hyatt's account justifies this step.

The chelæ in *P. osburnensis* are described (see above) as "tridentate." Dendy describes (1916) in the same way the chelæ of his *P.* (*Psammochela*) *elegans*, the smaller of which (fig. 6*c*, *c'*) resembles that of *P. osburnensis;* and in *P. fibrosa* Ridley (Ridley, loc cit.) the isochelæ are said to be "tridentate." Lundbeck (1905, p. 4) criticizes the use of this term (category) as confusing, since it covers two different forms of spicule, chelæ arcuatæ and ancoræ. This is undoubtedly so. On the other hand, it must be allowed that when the cheloid is very small, it is difficult to use the Levinsen-Lundbeck categories. For, assuming that the "tridentate" spicule is really either a well-defined chela arcuata or ancora with three teeth, and not some other form, the decision turns on whether the shaft has, in addition to the three teeth, alæ or not. And this is not easy to determine with certainty when the spicule is very small. Hence it would seem allowable, even necessary, to continue to use in practice the term "tridentate" for certain small spicules, although it is confessedly somewhat vague.

Levinsen and Lundbeck (Lundbeck, 1905, p. 6) regard the distinction between chela and ancora as so fundamental that they use it in distributing the species into genera, species with chelæ being assigned to one genus, species with ancoræ to another. Dendy apparently does not support this practice, for he includes in the same genus (1916, p. 126) a form, *Psammochela elegans*, with isochelæ (they are so designated, and the figures show three palmate teeth and no additional alæ) and one, *Desmacidon psammodes* Hentschel, with ancoræ. Hentschel, on the other hand, uses the distinction, at any rate in some cases, that of *Desmacidon-Homœodictya*, e. g., (Hentschel, 1911). Considering the existence of small cheloids, it seems to us that the distinction is one which can not be rigidly used in distinguishing genera.

Subfamily ECTYONINÆ.

Skeletal fibers, or spicular tracts, with echinating spicules which are characteristically spinose (acanthostyles).

Microciona Bowerbank.

Sponge body incrusting, or the incrustation may develop lobes and with continued growth become a complex, branched, ascending mass. Skeleton originally a basal plate bearing short, upright, plumose columns. In older forms the skeleton becomes an internal reticulum of spiculo-fiber, beset with short, plumose, radial fibers which represent the upright columns of the incrusting phase. Megascleres monactinal; the chief spicules smooth styles, the echinating spicules smaller and more or less spinose. Microscleres isochelæ, often accompanied by toxas and sometimes by sigmata.

Microciona prolifera Verrill. (Pl. LXII, figs. 31, 33; Pl. LXIII, figs. 35, 36; Pl. LXVI, fig. 57*a*, *b*, *c*, *d*, *e*.)

Microciona prolifera Verrill and Smith, 1874, p. 447.
Microciona prolifera Wilson, 1902, p. 396.
Microciona prolifera Wilson, 1911, p. 3.

The sponge when young forms thin incrustations on oyster shells, wharf piles, etc. As it grows older there rise up crooked, irregular lobes (Pl. LXIII, fig. 36). As the sponge grows older, the growth and formation of lobes may continue. This continued growth accompanied by branching and anastomosis will ultimately produce an intricately branched sponge (Pl. LXIII, fig. 35). Specimens of this type may reach a height of 150 millimeters.

The oscula are small apertures scattered here and there over the surface in general. They lead into canals which extend tangentially just beneath the dermal membrane. The pores are irregularly scattered in considerable abundance over the surface and lead into subdermal spaces. Thus the cavities which immediately underlie the dermal membrane are of two kinds, some afferent and some efferent. In the lobes of young specimens and in older branched specimens these superficial spaces communicate with abundant canals which ramify throughout the sponge interior (Pl. LXII, figs. 31 and 33).

Spicules.—Megascleres: (1) Styles (Pl. LXVI, fig. 57*a*, *b*), smooth and slightly curved, measuring 150 to 500μ by 8 to 12μ in an incrustation; 150 to 380μ by 8 to 14μ in one of the lobes of a young specimen; and 150 to 380μ by 8 to 16μ in an older branched sponge. The styles frequently have slightly enlarged heads and sometimes the heads are beset with very minute spines. (2) Small spinose styles 80 to 100μ by 6 to 8μ, which frequently have slightly enlarged heads (fig. 57*c*). Large numbers of very slender young megascleres are found throughout the sponge. Microscleres: (3) Isochelæ, 12 to 16μ long (fig. 57*d*). (4) Toxas, 10 to 40μ long (fig. 57*e*). Wilson (loc. cit.) records the microscleres, especially the toxas, as scanty in Beaufort specimens. We find that the granular sponge tissue tends to obscure the microscleres and that in partially macerated sections they may be found scattered in considerable abundance.

Skeletal framework.—The skeleton of the incrustations consists of a horny basal plate bearing closely set vertical horny columns from which megascleres project. From near the apex of each horny column a few large, smooth, and slightly curved styles project, forming a well-marked tuft. These styles measure 160 to 400μ by 8 to 10μ. The longest styles lie near the apex of the column, and some of them project beyond the surface of the sponge. Mingled with the mature styles are younger spicules of the same type, but slenderer and shorter. Projecting from the sides of some of the larger horny columns are a few small styles, 80μ by 5 to 6μ, some of them distinctly spinose, others with few and feeble spinulations. The skeleton of the incrustations contains longer styles than are found in the lobes of specimens like figure 36 or in the branches of older specimens like figure 35. In the incrustations we found a good many styles measuring 500μ long, while in the lobes and branches of older specimens they rarely exceed 380μ in length.

The skeleton of the constituent branches in a specimen like figure 35 consists of a reticulum of horny spiculo-fiber (Pl. LXII, figs. 31 and 33) which breaks up near the surface into independent radial fibers that extend out to and support the dermal membrane. From near the apex of such a radial fiber a few large, smooth, slightly curved styles project, forming a well-marked tuft. The longest styles are found near the surface, and many of them project beyond the surface of the sponge. These large styles average about 330μ by 10μ. Projecting vertically and obliquely from the sides of the radial fibers are large, smooth styles similar to those near the apex and a few small distinctly spinose styles (about 80μ by 7μ), together with others of about the same size but with few spinulations. It is these small styles which represent the echinating spicules of the subfamily. The spiculo-fibers of the interior bear similar echinating spicules. Wilson has pointed out that "the projecting (echinating) styles are few and scattered, spinose or smooth, the two types intergrading. The spinose type has numerous distinct though small spinulations on the shaft and a minutely tuberculate head. Spicules with only a few scattered spines occur, and, finally, quite smooth spicules with head end simply rounded and not enlarged."

The description given above applies both to the lobes of young specimens and the constituent branches of older ones. The skeleton of the older specimens (Pl. LXIII, fig. 35) differs, however, from that of the younger (fig. 36) in the following details. The spiculo-fibers in the former are considerably thicker than in the latter, due to the increased accumulation of spongin, and the styles reach a greater thickness. Some styles in the older sponge were found to measure 16μ in diameter while the greatest thickness observed in the younger sponge was 14μ. The small echinating styles are also more abundant in the former.

Family AXINELLIDÆ.

Sponge body ordinarily more or less upright, of a branching, lamellate, or cuplike habitus. But massive and even incrusting forms occur. Skeleton typically consists of ascending bundles of spiculo-fibers, from which arise subsidiary fibers that radiate to the surface. Skeletal fibers without spined echinating spicules, and typically plumose. The characteristic megascleres are monactinal. In addition to these, diactinal megascleres may also occur, and in some genera are the only form. Microscleres in the shape of microxeas, trichodragmata, or sigmata occur in a few genera; cheloid microscleres do not occur.

Axinella O. Schmidt.

Sponge body typically ramose; habitus varies, however, but while sometimes lamellate it is not cuplike. There is a firmer axial skeleton from which radial fibers pass to the surface. Axial skeleton not massive, but made up of ramifying and anastomosing spiculo-fibers. The radial fibers, which terminate in brushes of diverging smaller spicules, are joined by numerous short transverse connectives, the genus differing in this point from Phakellia in which the radial fibers are comparatively free. Skeletal fiber more or less distinctly plumose. Megascleres chiefly styles, but strongyles and oxeas may occur; scattered acanthostyles may also occur sparsely, as a vestigial feature. Microscleres generally absent, but trichodragmata are present in some species.

Axinella acanthifera, n. sp. (Pl. LXII, fig. 34; Pl. LXIII, figs. 38, 39; Pl. LXVI, fig. 59*a*, *b*, *c*, *d*.)

One specimen taken on Fort Macon beach.

Sponge body (Pl. LXII, fig. 34) lamellate, narrowing below to a stalk, expanded and divided into lobes above. Lobes in general foliaceous, separated by marginal notches; but the margin is also produced here and there into short, subcylindrical lobes. Upper part of sponge curved irregularly, so that the lobes lie in different planes. In this particular specimen growth has evidently resulted in an early division of the main axis, the two parts thus produced later on fusing at a point higher up. Height of specimen, 40 millimeters; width, 30 millimeters; thickness of lamella, 2 to 3 millimeters.

Color in alcohol gray brown with a tinge of yellow. Sponge firm, but flexible. Surface smooth and velvety.

Both surfaces are alike, appearing finely porous to the eye. The surface is depressed between the dermal brushes of projecting spicules; where greatly depressed, this is probably due to drying. Pores 60 to 85 μ in diameter are abundantly scattered between the dermal brushes. Fine canals less than 0.5 millimeter in diameter may be seen here and there beneath the dermal membrane, and parallel to the surface of the sponge. In places they radiate toward a central stripe, in which two or three minute apertures, about 0.5 millimeter in diameter, are arranged in a row. These are doubtless oscula. A very similar arrangement is described for *Axinella manus* Dendy, from the Gulf of Manaar. "The vents are small openings in the floors of stellately arranged or longitudinal grooves" (Dendy, 1905, p. 189).

Spicules.—(1) The most abundant megasclere is a smooth, slightly curved style, 160 to 260 μ long by 7 to 12 μ thick; commonly about 210 by 8 μ (Pl. LXVI, fig. 59*a*). This spicule makes up the bulk of both axial and peripheral skeleton. In the dermal brushes these styles, which constitute most of the brush, are thicker than elsewhere; common range, 160 to 200 μ by 10 to 12 μ. (2) A much stouter style, straight or nearly so, 160 to 240 μ by 12 to 20 μ (fig. 59*b*) is intermingled with the common form both in the axial and peripheral skeleton. (3) A very long and slender style, 400 to 600 μ by 6 to 7 μ (fig. 59*c*; Pl. LXIII, fig. 38, right side), is a characteristic element of the dermal brushes. Each brush includes a few (one to four) of these spicules, which project far beyond the others. They are broken off over much of the surface. (4) A small spinose style, 80 to 120 μ by 6 μ, with strong spines (fig. 59*d*), is present in the dermal brushes, in the radial fibers, in and projecting from the connectives that extend between the radial fibers. The spicule is not common anywhere, but is easily found on searching. Only those few which project from the connectives could be classified as "echinating" spicules. The bulk of them occupy positions similar to those of the common style. (5) Long and very slender rhaphid-like spicules occur in considerable abundance, scattered singly or in loose irregular sheaves; characteristic spicules measure 200 by 1 μ; more abundant in the ectosome than elsewhere. The sheaves are not to be confused with trichodragmata. It is questionable whether these spicules are rhaphides or simply stages in the development of the megascleres. Rhaphides in bundles have recently been described in a related sponge, *Raspailia* (*Syringella*) *rhaphidophora* Hentschel from the Aru Islands (Hentschel, 1912, p. 371).

Skeletal framework.—The skeleton (Pl. LXIII, figs. 38, 39) is divisible into an axial and a peripheral part. The axial skeleton is chiefly composed of longitudinal fibers which anastomose to some extent, but the unions between which are more commonly made by transverse or oblique connectives irregularly disposed. The longitudinal fibers are polyspicular, with abundant spongin, the spicules arranged longitudinally in the fiber or obliquely, with the point slightly projecting. The fibers vary greatly in thickness and character in different regions of the sponge. In the upper part they are about 30 to 70 μ thick and well filled with spicules, the spaces between them wider than the fibers themselves. Nearer the base the axial reticulum is closer and more compact. The individual fibers are here thicker, owing to the increase in the amount of spongin around the spicules, the latter now forming only an axial core. The fibers in the basal region range from about 60 to 120 μ in thickness, the interstices between them being about the thickness of or narrower than the fibers.

The connectives between the longitudinal fibers include, as a rule, one to three spicules, which are covered with abundant spongin. The spicules of a connective are often longer than the space between the fibers that are joined, and thus cross both fibers.

The peripheral skeleton is made up of radial fibers, including their dermal terminations, and connectives. The radial fibers are prolongations of the axial fibers that curve in an obliquely radial direction to the surface. They branch to some extent. The fibers are polyspicular; the spicules held together and just covered with spongin; the spicules longitudinal in the fiber or slightly oblique, with apex projecting. The fibers enlarge gradually as they approach the surface. At the outer end the spicules diverge somewhat, forming a dermal brush, which projects beyond the surface of the sponge.

Connectives extend between the radial bundles at about right angles to the latter. They include each one to three spicules, covered with spongin.

The dermal skeleton is made up of the projecting dermal brushes and the most superficial connectives.

Axinella is often defined as having plumose skeletal fibers. This term applies fairly well to the outer parts of the radial fibers in the Beaufort species, but not well to the rest of the skeleton, although the axial fibers and the inner parts of the radial fibers all show plenty of spicules placed obliquely, with the points slightly projecting; and after all, it is to this position of the spicule in the fiber that the "plumose" character is reducible.

In its external form this sponge closely approaches the European *Axinella flustra* (*padina*) Topsent (Topsent, 1896, p. 131; 1904, p. 139), a species which has trichodragmata about 40 μ long.

If we lay too great a stress on the presence of the spined styles, *A. acanthifera* might be removed to the Ectyoninæ and put in or close to Raspailia, in some of the species of which the acanthostyles are vestigial or absent, as in subgenus Syringella (which, to be sure, certain authors separate completely from Raspailia, making it an independent genus placed in the Axinellidæ). This is the familiar form of argumentation based on the presence or absence of a particular feature which leads in its application to the establishment of "parallel genera," viz, genera assigned to different groups, which yet resemble one another except in regard to the feature in question. From one point of view such parallel genera are looked on as temporarily defensible because of their practical utility, although artificial. From another they are regarded as natural groups which owe their general similarity to independent adaptation (or "convergent evolution"). But the character of the skeleton taken as a whole (cf. Vosmaer, 1912, p. 310) leaves little doubt that the sponge belongs with the other Axinella species. The presence of the spinose styles is accordingly to be interpreted as a vestigial feature which has never been quite lost, or, possibly, as an imperfect return (incomplete reversion) to an ancestral condition which had disappeared in the Axinellids.

The sponge resembles Raspailia, or, at all events, the species which center around *R. viminalis* O. Schm. (cf. Vosmaer, 1912, p. 313), in yet another respect, viz, in the presence of long projecting styles in the dermal brushes. In the *R. viminalis* type, regarded by Vosmaer (loc. cit.) as characteristic of the genus, each dermal brush includes a single, strong, far-projecting style, surrounded at its base by a tuft of diverging small spicules, generally styles, sometimes oxeas. There are, of course, many species generally assigned to Raspailia, in which the radial fibers (or the tufts of spicules which represent them) lack the large terminal styles, and a few such as *R. irregularis* Hentschel from the Antarctic (Hentschel, 1914, p. 121) and *R. hornelli* Dendy from the Gulf of Manaar (1905, p. 172), in which each dermal brush includes not a single such style, but a bunch of them. It will be noticed that in the Raspailia species the long-projecting styles are stouter than the surrounding spicules of the brush, whereas in the Beaufort sponge they are slenderer. Nevertheless, their presence, coupled with the occurrence of acanthostyles in the Beaufort sponge, greatly strengthes the already well-supported view that Raspailia is an intermediate form, leading up from the Ectyoninæ to Axinellids, such as Axinella. Any cleavage of this close series of forms, all the members of which continue to exist, into genera is largely a matter of convention based on historical accidents; that is to say, certain terms and not others of the series came to be studied first, and so became the nuclei of genera.

As to the course of opinion with respect to the position of Raspailia, it may be recalled that Ridley and Dendy (1887) first gave the genus a definite postion in modern classification by assigning it to the Axinellidæ. Topsent (1894*b*) removed it to the Ectyoninæ. Dendy (1895, p. 46) assented, but remarked that the genus was intermediate between the two groups, Ectyoninæ and Axinellidæ. Topsent has been followed generally, but Vosmaer (1912), without mentioning groups by name, keeps the genus in the same series with Axinella, Phakellia, Acanthella, etc. Dendy (1905, p. 172) apparently departs from his former view and now regards the resemblance of the Raspailia species to Axinellidæ as strong but "superficial." He says "it is evident from the presence of the spined echinating styli (though these may be vestigial) that they are really highly modified Ectyoninæ." The Axinellidæ are looked on as a polyphyletic group. Dendy recently (1916, p. 96) is disposed to abandon the group entirely and to include the genera such as Axinella, Phakellia, etc., in the Haploscleridæ, thus virtually returning to Vosmaer's position (1887, p. 335). Hentschel (1912, p. 413) brings out the skeletal resemblances between the Ectyonine genera centering around Raspailia and certain Axinellidæ, and inclines to regard it as due to kinship and not to convergent evolution (position of Dendy in 1895).

Acanthella O. Schmidt.

Form generally lamellate, consistency cartilaginous. Surface aculeate or conulose. If radial fibers are developed, they are weak, except in the basal part of the sponge, as compared with those of Phakellia; connectives between the radial fibers are lacking. Without microscleres.

Acanthella corrugata, n. sp. (Pl. LXIII, fig. 37; Pl. LXV, figs. 46, 47; Pl. LXVI, figs. 56*a*, *b*, *c*, *d*, *e*.)

One specimen taken on Fort Macon beach after a moderate southwest blow.

Sponge body (Pl. LXIII, fig. 37, taken obliquely from above) a folded lamella; folds tend to anastomose and inclose cuplike compartments. Only one of the cuplike spaces is completed, and this is open at the bottom; there are several other partially surrounded spaces. Below, the sponge narrows to a short peduncle; in side view the body has about the shape of an open fan. Total height, 65 millimeters, greatest horizontal diameter, 95 millimeters; common thickness of lamella about 5 millimeters, extreme basal portion of sponge about 10 millimeters thick. Above, the lamella diminishes to a fairly thin margin.

Both surfaces of the sponge are corrugated with more or less parallel ridges, about 2 millimeters apart, radial to the margin, converging and dying away toward the base. These are thickly beset with small conuli; between the ridges the surface is smooth. The extreme basal part, lacking well-defined ridges, is irregularly conulose. The surface is hispid, with spicules that project at the conuli.

Color bright orange red. Consistency firm, but not rigid, fairly elastic, of the kind known as cartilaginous.

There is no difference between the two sides of the lamella. A few scattered inconspicuous oscula about 1 millimeter in diameter were found, and open pores, about 40 μ in diameter, occur scattered over both surfaces. From the pores small pore canals pass through the outer stratum of the ectosome into subdermal canals, which extend parallel to the sponge surface. Characteristic subdermal canals measure 100 to 400 μ in diameter, the smaller sizes being the more common. From them canals lead more or less radially into the interior. Large canals are not abundant in any part of the sponge. The ectosome is collenchymatous and about 250 to 350 μ thick. Its superficial stratum is fibrous; that is, the cells are elongated and rather compactly arranged parallel to the surface. From the ectosome wide tracts of collenchymatous tissue pass into the interior, marking out the pathways of the main canals.

Spicules.—The megascleres (Pl. LXVI, fig. 56*a* to *c*) are styles which fall in two very distinct classes, although intergrades can be found.

(1) A stouter form (fig. 56*a*), smooth, cylindrical, usually slightly curved; the characteristic spicule of the peripheral skeleton. In the upper part of the sponge this spicule generally measures 400 to 600 μ by 10 to 12 μ. In the lower basal part of the body it is larger, reaching 700 μ by 20 μ. The oxeate modification sometimes occurs (fig. 56*b*). Intermediate forms, between style and oxea, with irregular, imperfect ends, also occur (fig. 56*c*, *d*, *e*).

The stouter form of style is present in small number in the mesial skeleton, sometimes projecting from the individual fibers. A short form, often bent, about 200 to 350 μ by 16 to 20 μ occurs with some frequency.

(2) A slender form of style 400 to 500 μ by 3 to 8 μ, the commonest thickness being about 4 to 6 μ, is the characteristic spicule of the axial (mesial) skeleton. This spicule is smooth, cylindrical, usually slightly curved, sometimes exhibiting more than one bend. The oxeate modification occurs.

Skeletal framework.—The framework includes an axial portion, which, since the sponge is essentially lamelliform, is better designated mesial, and a peripheral portion.

The mesial skeleton is a reticulum made up of longitudinally coursing (i. e., extending from base to free margin of sponge) fibers, which branch and anastomose (Pl. LXV, figs. 46 and 47). In the basal part of the sponge this portion of the skeleton becomes quite thick; everywhere it occupies all but the superficial zone of the body. The fibers are cylindrical and plurispicular, with abundant spongin; the spicules arranged more or less longitudinally. Common range in thickness of individual fibers, 40 to 100 μ.

The peripheral skeleton consists chiefly of obliquely radial fibers, into which the mesial skeleton is produced (figs. 46 and 47). They are slender in the marginal region of the lamella, but become thicker below, in the basal region becoming strong and plumose. The fibers include but little spongin, only enough to hold the spicules together. The radial fibers branch to some extent, and at the distal end the spicules fray out, forming a bunch or bunches, generally divergent in character. These outermost spicules are embedded in spongin only at their very base. The radial fibers extend into the conuli. If, as often happens, the conulus is subdivided into secondary conuli, each of these receives a spicule or two or a bunch of spicules.

The peripheral skeleton includes also radial megascleres, which beset the mesial skeleton on its outer surface, between the radial fibers. They extend out toward the surface, and are especially conspicuous in the depressions between the ridges or other conulose elevations. These spicules belong to the stouter form of style.

Vosmaer has recently (1912) made an attempt to establish the genera Axinella, Phakellia, Acanthella, and Raspailia on more definite anatomical grounds. He finds that a new genus, Phacanthina, must be made for Schmidt's *Acanthella obtusa*.

Vosmaer finds that the species which he has studied, representing the above five genera, differ in definite points as to the character of the skeletal framework, and he therefore concludes that, in the diagnosis of the genera, the character of the framework should play an important part. How well the numerous species hitherto grouped under the above genera, when studied anatomically, will fit into the five skeletal schemes described by Vosmaer is, of course, a question. But there is no doubt that the distinguished spongologist, whose recent death entails such a loss upon zoological science, should be followed in the resolve to learn more definitely about the skeletal framework of these sponges and to use the data in classification.

According to Vosmaer's generic schemata, Acanthella and Phacanthina lack the radial fibers (extraaxial funiculi) which are found in Axinella, Phakellia, and Raspailia. The Beaufort sponge would therefore fall in Phakellia. But it seems not impossible that some of the peculiarities of the skeletal framework which Vosmaer has brought out in his stimulating paper are such as distinguish species rather than genera.

In listing the sponge under *Acanthella* we rely for the present on the assumption that the cartilaginous consistency, and especially the aculeate surface, when coupled with a lamellate form and the general type of Axinellid skeleton, are signs of kinship.

Species of Acanthella, in the usual sense, are known from the Red Sea: *A. aurantiaca* Keller (Keller, 1889–91; Topsent, 1906*b;* Row, 1911); Mediterranean: *A. acuta* Schmidt, *A. obtusa* Schmidt (O. Schmidt, 1862; Topsent, 1901*a*); Australian waters: *A. stipitata* Carter, *A. tenuispiculata* Dendy (Dendy, 1896); Gulf of Manaar: *A. carteri* Dendy, *A. flabelliformis* Keller (Dendy, 1905); Torres Straits: *A. pulcherrima* Ridley (Ridley, 1884; Ridley and Dendy, 1887); Aru and Kei Islands: *A. euctimena* Hentschel, *A.* sp. Hentschel (Hentschel, 1912).

It would seem that Acanthella flourishes in warm waters, although Vosmaer some time ago (1885) referred a sponge taken in the Arctic Ocean, *A. multiformis*, to this genus.

KERATOSA.

Family DARWINELLIDÆ (APLYSILLIDÆ auct.).

Keratosa with eurypylous and large flagellated chambers; with a skeleton composed of separate horny fibers that ascend from the base of the sponge and are simple or branched, or the skeleton may be reticulate; spicules of spongin may also occur; the spongin fibers contain a medulla or pith and lack foreign mineral particles.

Aplysilla F. E. Schulze.

Incrusting or lamellar forms; skeleton nonreticulate, composed of separate fibers; without spongin spicules.

Aplysilla longispina, n. sp. (Pl. LXIV, fig. 42; Pl. LXV, figs. 45, 48; Pl. LXVI, fig. 64*a*, *b*, *c*, *d*.)

One large, incrusting specimen taken on the piles of the Morehead railroad pier, near the town end, just below low-water mark.

Sponge (Pl. LXIV, fig. 42) 1 to 20 millimeters thick, covering an area 150 millimeters in diameter, apparently with unlimited lateral growth. The surface is covered with numerous slender, sharp conuli several millimeters high (the range is 1 to 5 millimeters, the common height about 3 millimeters) and a variable distance apart (often about 3 to 5 millimeters), frequently but not always connected by thin, sharp-edged ridges or folds. Conuli in general simple, but not uncommonly bifid or trifid at the apex. Surface very uneven because of numerous ascending portions, all of which are low, irregular, and so vaguely delimited as not to merit the name of lobes. A few oscula, 1 to 3 millimeters in diameter, are scattered over the surface.

Color, sulphur yellow, turning instantly in alcohol to an indigo blue. Sponge soft and elastic; interior cavernous (Pl. LXV, fig. 45).

The skeletal fibers are simple, or branched somewhat in elk-horn fashion (Pl. LXVI, fig. 64*a*, *b*, *c*). At the under surface of sponge they expand into thin, basal, horny plates, which sometimes, at any rate, connect with one another. The fibers extend vertically upward into the conuli, reaching the apex of the latter (Pl. LXV, fig. 45). The simple fibers support each a single conulus, and each terminal division of a branched fiber supports a conulus or one of the subdivisions of a primary conulus. The more complex fibers thus support a number of conuli.

The fibers measure 100 to 250 μ in diameter just above the basal plate and 15 to 30 μ near the tip. The pith, which consists of successive thimble-shaped segments of varying length, forms about half of the fiber in the basal portion. The spongin wall is clearly stratified (Pl. LXVI, fig. 64*d*). The fibers are generally smooth and have no inclusions, but occasionally foreign bodies are found in them.

The surface of the sponge is formed by a dermal membrane 20 to 40 μ thick, the body of which consists of not very closely packed mesenchyme cells, which are elongated parallel to the dermal surface and the neighboring spaces. The dermal membrane is traversed by closely set, short, radial canals, 75 to 125 μ in diameter and about 30 to 60 μ apart. These open internally into large subdermal spaces. At the outer dermal end these canals are now closed in by thin membranes, each of which in life is probably perforated by several pores. In the actual specimen the pores are closed. The subdermal spaces are wide just beneath the dermal membrane, but, descending vertically from the surface, they become gradually narrower, terminating in the inhalent canals, which are not marked off by any definite limit from the subdermal spaces. The subdermal spaces and the inhalent canals open directly by small prosopyles, about 4 to 8 μ in diameter, into the flagellated chambers, which are generally, but not invariably, longer than wide, 80 to 130 μ long, 60 to 100 μ wide, and which open directly by wide mouths into the exhalent canals.

The Beaufort sponge is probably to be looked on as a migrant from the coast farther south. A Bahama species of Aplysilla is known, *A. compressa* (Carter), but this is an erect lamellar form (Lendenfeld, 1889, p. 704).

The Mediterranean species, *A. sulfurea* F. E. Schulze, recorded also from Australian seas, the European coast of the North Atlantic, and from Juan Fernandez (Thiele, 1905, p. 488), resembles the Beaufort sponge in color, the yellow turning to violet in alcohol (Topsent, 1904, p. 56), or gradually becoming blue as the sponge dies in the air (F. E. Schulze, 1878). The conuli are much lower than in the Beaufort sponge, only 0.5 to 1 millimeter high and about 1 millimeter apart.

The Beaufort sponge is nearer to an Australian form, *A. violacea* (Lendenfeld, 1889, p. 704). This is an incrusting species with unlimited lateral growth and conuli about as high as in the Beaufort species. The conuli are, however, more closely set, and the natural color is dark violet. Moreover, there is a basal spongin plate which contains large sand grains, and the flagellated chambers are smaller (60 to 100 μ long by 30 to 40 μ wide) than in *A. longispina*.

Recent writers (Topsent, 1905; Dendy, 1905 and 1916; Row, 1911; Hentschel, 1912) do not separate the Darwinellidæ and Aplysillidæ of Lendenfeld's monograph (1889), but combine them in one family, for which Topsent uses the heading, Darwinellidæ, thus following in essentials Merejkowsky (1879) and Vosmaer (1887). The other authors cited above use the name Aplysillidæ. Topsent is obviously in the right, since the type genera of the families combined, *Darwinella* F. Müller and *Aplysilla* F. E. Schulze, were established in 1865 and 1878, respectively.

Family SPONGELIDÆ.

Keratosa with eurypylous and large flagellated chambers, with a skeleton composed of separate horny fibers that ascend from the base of the sponge and are simple or branched, or the skeleton is more commonly reticulate. Horny fibers without pith, generally containing abundant foreign mineral particles. Skeleton may be reduced, then consisting of foreign particles usually held together by a little spongin, but the latter may be absent.

Pleraplysilla Topsent.

Thin, incrusting forms, with low conuli, supported by spearate areniferous fibers ascending from base of sponge and characteristically undivided.

Pleraplysilla latens n. sp. (Pl. LXIV, fig. 40.)

Sponge occurs in the shape of thin, colorless incrustations on oyster shells, commonly along with *Microciona prolifera*. Under the piers along the "town front" proved to be the best collecting ground. The sponge is not nearly so abundant as Microciona, but is not rare. It is, however, inconspicuous. It contains abundant embryos during July and August.

Surface covered with small, sharp conuli, commonly 0.5 to 1 millimeter apart. Thickness of sponge from base to apex of conulus about 1 millimeter, usually something less; body of sponge itself about one-half that thickness. Upper ends of the skeletal fibers extending into conuli are conspicuous, reflecting the light. The fiber in some cases extends an appreciable distance beyond the substance of the conulus; but this may be an effect due to contraction.

The dermal membrane in stained preparations exhibits narrow bands, which prove to be linear thickenings about 20 μ wide, due to aggregations of mesenchyme cells on the under surface of the membrane. The mesenchyme cells are elongated in the direction of the bands. The bands radiate from the apices of the conuli, often about eight from a conulus, soon branching and passing into a network of similar bands which occupy the sides of, and the areas between, the conuli. The meshes of this network are polygonal, irregular in size, the diameter ranging from 70 μ to 250 μ. The network is easily seen with a lens in a lightly stained preparation in alcohol. The bands are sometimes so arranged that primary meshes of the reticulum are subdivided. The meshes themselves are riddled with small pores 12 to 24 μ in diameter. In the actual specimens examined the pores were open in some regions, closed in others.

The dermal reticulum of bandlike thickenings just described is a structure similar to that found in *Aplysina acrophoba*, *Aplysilla sulfurea*, species of Spongelia, and other horny sponges (F. E. Schulze, 1878, 1879*a*). It is of the same general character as that found in *Aplysilla longispina* nobis (Pl. LXV, fig. 48), but in the latter species the bands are relatively very thick and strongly developed, so much so that they constitute lateral walls of distinct, though short, canals, which may be said to traverse the dermal membrane radially.

Beneath the dermal membrane there is a nearly continuous subdermal space from which canals, presumably afferent, pass vertically downward into the sponge interior. These canals are numerous, often about 0.5 millimeter apart, although there is no regularity in their distribution. The mouths of the canals, reaching about 300 μ in diameter, are easily seen through the dermal membrane. With the lens they look like surface apertures and give to the sponge a porous appearance.

Numerous tangential canals, presumably efferent, extend just below the dermal membrane. These are long and branching, the larger about 0.5 millimeter wide. The membrane covering them is without conuli, and lacks or nearly lacks the system of bandlike dermal thickenings. It is in general aporous, but a few scattered pores occur of about the same size as those found elsewhere. Open oscula 200 to 250 μ in diameter were observed scattered over the surface of the sponge.

The flagellated chambers are longer than wide, commonly ellipsoidal, often about 100 to 120 by 70 to 90 μ. They may be larger, reaching 175 by 100 μ, sometimes slightly curved in the direction of the greater axis. Still longer tubular chambers occur here and there, sometimes with indications of branching. These bespeak the primitive nature of the canal system. The chambers are perforated by numerous prosopyles 8 to 10 μ wide, and open by wide apopyles directly into the efferent spaces. The chambers are abundant below the general subdermal space, except in the regions of the main tangential canals, below which there are, however, some.

The skeleton consists of simple independent fibers, 40 to 60 μ thick at about the middle, ascending from the basal surface of the sponge into the conuli. They are made up of spongin and mineral particles, the latter including sand grains, fragments of sponge spicules, occasional entire spicules, and diatom shells. The mineral particles, except at the base of the fiber, nearly or completely fill it. Close to the base the mineral matter tapers away to a thin core, leaving the surrounding spongin very evident. In this region and at other points also along the course of the fiber it is possible to see that the spongin is laminated. At the very base the fiber expands into a thin basal plate of spongin. The fibers sometimes extend vertically, or nearly so, from base to conulus. But usually they extend obliquely from the base upward, often occupying throughout a large part of their course a more or less horizontal position. They are sometimes fairly straight, but frequently curved or bent. They are characteristically simple, neither branching nor connecting. Rarely a fiber is found with a lateral branch; and, again, rarely two fibers may come in contact and fuse, thus producing the appearance of a fiber that divides basally.

Topsent some years ago (1905, p. CLXXXV) described a new and interesting sponge for which he created the genus *Pleraplysilla.* Topsent's sponge, *P. minchini*, was dredged off the French channel coast at a depth of 30 meters. The sponge is incrusting, about 1 millimeter thick, except in spots where the thickness reaches several millimeters. The color is chocolate. The largest specimen measured 25 centimeters in diameter. The surface is beset with conuli 1.2 to 2 millimeters or more apart. The skeletal fibers are characteristically simple but, especially in the thicker parts of the sponge, may send out two or three branches; they are 100 to 110 μ thick below. The flagellated chambers are eurypylous and measure about 90 by 35 μ. The Beaufort sponge is evidently another species of this genus.

For Pleraplysilla and another sponge *Igernella* (*Darwinella*) *joyeuxi*, from the Gulf of Mexico, Topsent, *loc. cit.*, creates the family Pleraplysillidæ. Igernella having horny spicules would be a good Darwinella if the fibers of its skeletal reticulum were not areniferous. But this latter characteristic excludes it from the Darwinellidæ (Aplysillidæ of some). Its horny spicules, on the other hand, exclude it from the Spongelidæ. The sponge is an intermediate between the Darwinellidæ and Spongelidæ, and Topsent's family provides a place for it, although, if Pleraplysilla is removed, as we suggest (see below), the name of the family will have to be changed.

Pleraplysilla, while it will not go in the Darwinellidæ because of its areniferous fibers, can not, it seems to us, be excluded from the Spongelidæ. It takes its place at the base of the latter family, its very simple fibers leading up to the more complicated, but still independent, ones of *Spongelia spinifera.* It is generally recognized that the separation between the Darwinellidæ and the Spongelidæ is not a sharp one. Dendy (1905, pp. 203, 207) points out that *Spongelia spinifera* F. E. Schulze and Megalopastas Dendy are intermediate forms. Igernella and Pleraplysilla are also intermediates, although not intermediate in respect to the same points.

Family SPONGIDÆ.

Sponges with small flagellated chambers, 20 to 50 μ wide, and a skeleton, generally in the shape of a reticulum, composed of solid or pithed, horny fibers.

Subfamily STELOSPONGINÆ.

Spongidæ in which main fibers and connectives are generally distinguishable in the skeletal reticulum. The main fibers may be simple but are generally more or less fascicular. Between the fascicular fibers, or between the simple main fibers in species without fascicles, the skeletal meshes are much larger than in the Eusponginæ.

Hircinia Nardo.

Stelosponginæ with filaments in the ground substance and in which the connectives are characteristically attached to the main fibers by diverging roots which extend along the main fiber in one plane.

Hircinia ectofibrosa, n. sp. (Pl. LXIV, figs. 41, 43, 44; Pl. LXVI, fig. 61.)

Taken several times on Fort Macon beach after moderate gales; six specimens available for study; probably growing on the "Fishing Bank" off Beaufort Inlet and in similar places, and to be looked on as an outlying member of the Florida-West Indian fauna.

The chief characteristics of the species, as brought out through the comparison of specimens, no two of which agree in detail, are: The predominantly simple character of the main fibers and the connectives; the existence of dermal connectives; the tendency for the outer ends of the radial fibers to become fascicular through the extension of, and union between, the roots of the surrounding dermal connectives.

The shape of the body in most of the specimens is platelike, the plate probably standing more or less vertically; the platelike body may be produced into lobes. The platelike shape is not universal, for in the type specimen (Pl. LXIV, fig. 41) there is simply a common basal part dividing above into a few subcylindrical or flattened lobes. The specimens vary in total height from 50 to 130 millimeters; in thickness from 10 to 35 millimeters.

The sponge is beset with sharp conuli connected by thin interconular ridges, which divide the surface into rounded or polygonal, depressed areas. The conuli project 1 millimeter or less above the ridges but 1.5 to 3 millimeters above the level of the depressed areas. They are 2 to 4 millimeters apart, these distances representing usually the diameters of the interconular depressed areas, but the bounding ridges are sometimes absent, with the result that interconular areas are produced larger than the normal. The ridges themselves vary in height from a fraction of 1 millimeter to 2 millimeters. The specimens studied all being beach specimens, although fresh and in good condition, it is quite probable that in them the conuli and interconular ridges are sharper, and the depressed areas deeper, than in the living sponge, owing to contraction incident upon partial drying.

Over a part of one specimen the radial fibers (see below) project from the summit of the conuli. But this is a condition obviously pathological (in a wide sense) and of no classificatory value.

The conuli are generally vertical to the surface, but on parts of several of the platelike specimens they incline obliquely upward toward the free margin of the sponge. Thus several interconular ridges, together with the depressions between them, are combined along lines that radiate toward the free margin. This leads to the appearance of ridges and furrows, radial to the margin, that may be 15 millimeters long, a type of surface architecture which approaches that shown in some of Hyatt's specimens of *H. campana* (Hyatt, 1877, Pl. XVII, fig. 28). In such regions the dermal connectives (see below) in a ridge are combined to form continuous fibers which extend the length of the ridge; these are connected by transverse, simple fibers, and thus a ladderlike dermal skeleton is produced.

Foreign mineral particles are present in considerable abundance on the surface and in the ectosome, which thus sometimes to a depth of 180 μ appears dense and whitish as compared with the light yellowish-brown interior. The particles include the usual sand grains, spicule fragments, and foraminifer shells or bits of the same. They are scattered; that is, are not abundant enough to be massed together so as to form a continuous sand cortex. The particles for the most part are small, but in several specimens large sand grains, up to 250 μ in diameter, are abundant among the smaller bits.

A surface reticulum consisting of pore areas separated by trabeculæ containing closely packed sand grains is not present in these specimens. But this reticular appearance, which is so common in horny sponges and, because of the sand grains in the trabeculæ, so conspicuous in some Hircinias, is, as has been shown (Wilson, 1902, p. 405), greatly influenced by the physiological state; that is, whether the pores are open or not. There are in several specimens of the present species indications that in the active state pore areas will be found, 150 to 250 μ in diameter, each containing one or more pores 25 to 70 μ in diameter, and separated by interareal trabeculæ of thicker dermal membrane full of mineral particles. Actually only a few pores are open.

Subdermal cavities 2 to 3 millimeters wide are abundant, more so in some specimens than in others. The sponge interior is porous, with canals up to about 3 millimeters in diameter. The flagellated chambers measure about 36 by 28 μ. Oscula, 1 to 4 millimeters in diameter, are scantily scattered over both surfaces in the tabular specimens.

The filaments (Pl. LXVI, fig. 61) are very abundant. They are about 6 μ in diameter at the middle, 3 to 4 μ near the ends. The terminal enlargements are oval and about 9 μ thick. The filaments are smooth and for the most part colorless and unspotted, but in one of the specimens some of the filaments are "spotted," others not. The "spotted" or "unspotted" condition is obviously of no classificatory value. The filaments in some regions, especially around some of the canal walls, are arranged in more or less distinct tracts.

The surface color varies from whitish to a dull purple. The natural color has probably in part faded out. The sponge is firm, but compressible and elastic.

The skeleton includes main fibers and connectives. The main fibers ascend in the middle of the plate, or lobe, and branch, the branches curving outward in the usual way as radial fibers, which terminate in the conuli. The ascending and radial fibers are alike, and both are referred to here, in accordance with the general usage, as main fibers. The radial fibers, in macerated skeletons, are 1.2 to 2 millimeters apart.

The main fibers (Pl. LXIV, figs. 43, 44) are characteristically simple, solid fibers, 100 to 200 μ thick, well filled with mineral particles (sand grains, bits of sponge spicules, and foraminifer shells), all comparatively small in size, there being no large sand grains or shells to swell out and distort the fiber. The spongin is stratified. In some specimens, but not in others, the outermost ends of the main fibers, and the dermal connectives as well, are composed of a much paler spongin than the rest of the skeleton, in which the spongin is yellow. This difference is probably associated with some individual difference in growth activity.

Whenever the main fibers appear in any degree fascicular, this is due to one of two causes, as follows:

(1) Two or even three main fibers may be closely approximated, or a main fiber may branch obliquely, the two or three branches continuing to run more or less parallel and close together. Between such fibers or such branches, respectively, the connectives are, of course, very short, and the several fibers, together with their connectives, constitute a compound fiber such as is characteristic of *Stelospongia*. Such compound fibers have a total thickness of about 0.5 millimeter. This condition is found here and there in the specimens studied, but is comparatively rare. In the literature on the Stelosponginæ when the term "fascicular fiber" is used, writers seem usually to have in mind a compound fiber of this kind.

(2) A connective unites with a main fiber by several roots, the middle about transverse to the fiber, the upper and lower oblique to the fiber. Thus the roots of a connective attach themselves to a considerable extent of the main fiber, forming altogether a sort of triangular plate. If now, as often happens, several connectives attach to the same immediate region of a main fiber, but on different sides, the main fiber in that region is surrounded by several sets of roots, and thus may appear "fascicular," although in a different sense from that understood under (1). Between any two successive sets of roots which meet it the main fiber is, as a rule, obviously simple (fig. 44), but in places the roots spread up and down the fiber so far that successive sets meet one another. The main fiber then appears not as an independent fiber, but as an axial tract, distinguishable because of its mineral contents, extending through an elongated, and close, reticulum. Such a condition is found here and there in the interior of the sponge. It is commoner in the outer layer of the body, between the dermal connectives and the most superficial of the inner connectives, which usually lie about 1 millimeter below the former.

In its outermost part, within a conulus, the main fiber often remains simple; but in this region the fibers vary considerably, and the variants need to be described. They are as follows:

(1) The outer end, intraconular portion, of a main fiber is, as said, often simple and so full of mineral particles as to show very little spongin. In a typical case it extends 500 μ beyond the attaching roots of the dermal connectives and ends in a slight enlargement, each dermal connective meeting the fiber by several roots. The terminal portion of the fiber may show a perforation or two, due probably to the fact that mineral particles here have only recently been surrounded by the spongin of the fiber.

(2) The roots of the dermal connectives may extend very obliquely upward (and downward) along the main fiber. These roots, thus entering a conulus from several sides and extending up toward the apex, become interconnected by short fibers, and so may give rise to a very perfect trellis, suspended like a tent, as it were, from the uppermost part of the main fiber. This is, perhaps, the commonest condition of the intraconular portions of the main fibers in the specimens studied.

(3) In exceptional cases the main fiber, near its outer end, may divide, the two branches extending into the same conulus. They are connected in a close and complex way, the connectives themselves being so united as to constitute reticula. Terminally the two branches may end in a common enlargement, which maceration shows is a spongin reticulum very full of mineral fragments. In such a case the intraconular skeleton is fairly to be classed as "fascicular" in the sense of being a compound, Stelospongia-like fiber. A variant of this condition is found where two or three main fibers which, in the periphery of the sponge, at least, are not branches of a common fiber, converge and enter the same conulus, within which they are united by short connectives.

The most superficial, or dermal, connectives lie in the ectosome just below the dermal surface, passing from the outer end of one main fiber to that of another. Except where interconular ridges are not developed, they lie in and close to the free edge of the latter. In general they are single, simple fibers connecting with the main fibers by several roots. They are commonly united by other dermal fibers that may be called interconnectives, but these are few in number and irregular in distribution. The result is that the dermal skeletal reticulum has, in general, large meshes that approach the squarish or rectangular shape. Characteristic meshes measure 1.6 millimeters by 1.9 millimeters, 2.2 millimeters by 2.5 millimeters, 2.5 millimeters by 2.5 millimeters, 2 millimeters by 4 millimeters. The dermal connectives in some specimens are very different in appearance from the internal connectives, in that they are slenderer than the average internal connective and of very pale spongin well filled with mineral particles. In other specimens they differ from the internal connectives only in containing more mineral particles, while in still other specimens the dermal connectives do not differ in appearance from the internal ones. The difference in appearance between dermal and internal connectives is thus inconstant. It is, perhaps, in part correlated with a difference in growth activity.

In one specimen the dermal connectives depart, over much of the surface, from the type. Typical connectives are developed, but the surface as a whole offers the following deviations from the type:

(*a*) Instead of a few interconnectives, a comparative abundance of fibers develop between and around the principal connectives, thus producing reticula which encroach upon the interconular areas. Such reticula may be very fine.

(*b*) In this specimen as in some others a good many large sand grains are scattered through the ectosome and on the surface; but, whereas in the other specimens they have not been incorporated in the skeletal fibers, in this specimen a great many of the dermal connectives include large grains that measure up to 250 μ in diameter. The grains lie in a longitudinal series in the connective and are surrounded by a thin layer of spongin. They may form a continuous series or be separated by intervals in which the connective remains of the usual thickness, about 40 to 50 μ. Such fibers resemble those of the species grouped together by Lendenfeld under the subgenus Psammocinia (1889, p. 579).

(*c*) A further complication is present in that some of the dermal connectives that have incorporated large sand grains are fascicular. Such "fascicular" fibers consist of several simple connectives that lie close together and are interconnected. Sometimes all the longitudinal components of such a fiber apply themselves to the same sand grain. Fascicular connectives of this kind may be 350 μ wide, the constituent being strands only 20 μ thick.

The peculiarities of the dermal skeleton in this specimen are probably no more than individual differences. The specimens form a series, at one end of which are those without large sand grains; in the middle, those with large sand grains in the ectosome but not in the skeletal fibers; at the opposite end, the specimen in which many dermal connectives have incorporated the sand grains in question.

The internal connectives are composed of yellow spongin and in general are without, or have only scanty, mineral contents. Close to the surface they may exceptionally contain more, but even then the mineral contents can not be said to be abundant. They range in thickness from about 35 μ to 175 μ. The connectives are characteristically simple, the meshwork correspondingly coarse. The skeletal meshes in the macerated skeleton, which with the most careful treatment shrinks in some degree, may reach 2 millimeters in diameter. Common sizes for the largest meshes are: Width 1.5 millimeters, with a radial diameter of 1.2 millimeters; width 1.2 millimeters, with a radial diameter of 1 millimeter; width 1.2 millimeters, with a radial diameter of 500 to 600 μ. In the case of such meshes neighboring connectives are not united together. But very commonly neighboring connectives are united together by a few other fibers—"interconnectives," as they may be called. The size of the mesh is thus correspondingly reduced, although characteristically it still remains large, typical diameters ranging from 300 to 600 μ.

The interconnectives often become so numerous and complex that they, together with the connectives, form reticula that extend between the main fibers, thus making an approach to the condition characteristic of *Hircinia fœtida* (Schulze, 1879*b*, Pl. III, fig. 3), although the reticula in question are coarser and more irregular than in the latter species.

Position of H. ectofibrosa in the genus.—The Beaufort species is in that group of forms which center around the Mediterranean sponges described by F. E. Schulze as *Hircinia variabilis*, in which the main fibers are simple or only slightly fascicular and the connectives characteristically simple. Lendenfeld combines these forms into a subgenus, Euricinia. In his definition of this subgenus the following clause must now be omitted: "but no large sand grains joined by slender short fibers occur" (1889, p. 554).

In the possession of a dermal skeleton the Beaufort species appears to be nearly unique in the subfamily. Lendenfeld says (loc. cit., p. 477) that the species of Stelospongia are destitute of a special dermal skeleton, by which he must mean one that lies in the ectosome, close to the surface and above the level of the subdermal cavities. So, too, the described species of Hircinia, in general, lack a dermal skeletal reticulum, which is, however, present in *H.* (*Oligoceras*) *conulosa* (Ridley) (Ridley, 1884, p. 599; Lendenfeld, loc. cit., p. 535).

The presence of large sand grains in the skeletal fibers is the central fact on which Lendenfeld bases his subgenus Psammocinia (loc. cit., p. 579). As to whether Psammocinia is a natural group or an assemblage of phænotypes we are not in a position to form an opinion, although it is certain that the mineral content of the skeleton is exceedingly variable, both in total amount and kind, in what must be regarded as a single species. F. E. Schulze long ago pointed out how variable is the amount of mineral content in the ectosome of *H. variabilis* (1879*b*, p. 14).

The resemblance of *H. ectofibrosa* to some of the Mediterranean specimens of *H. variabilis* involves surface details. These are the sponges now assigned to var. *hirsuta*, in which the conuli are high and sharp and often in rows: "gewöhnlich in kurzen unregelmässigen Kämmen, welche Bogen bilden und in einander übergehen" (Schmidt, 1862, p. 33). They are evidently very similar to the Beaufort species.

The Beaufort sponge is doubtless an outlying member of the Florida-West Indian fauna. Several species of the genus have already been recorded from the Florida-West Indian waters: *Hircinia campana* (Lamarck), *H. arbuscula* (Schmidt), *H. acuta* (Duchassaing et Michelotti), *H. cartilaginea* (Esper), *H. purpurea* Hyatt, by Hyatt (1877); several under "Polytherses" by Duchassaing and Michelotti (1864, p. 67); *H. caracensis* Carter (Carter, 1882, p. 273), *H. tubulosa* Carter (Carter, 1884, p. 203); *H. purpurea* Whitfield, and *H. atra* Whitfield (Whitfield, 1901); *H. acuta* (Duchassaing et Michelotti), *H. variabilis* F. E. Schmidt, *H. fœtida* (Schmidt) var. *cuspidata* Wilson, by Wilson (1902). Not all of these species are recognizable.

One of the West Indian forms just recorded offers resemblances to the Beaufort species. This is *H. campana* var. *fixa* Hyatt (Hyatt, 1877, p. 546, Pl. XVII, fig. 28). The case of *H.* (*Spongia*) *campana* (Lamarck) as occurring in the West Indies is as follows: Duchassaing and Michelotti (1864, p. 68) identified certain forms as belonging to this species. Hyatt (loc. cit.) grouped under the same heading a variety of West Indian sponges. He tells us that the variation in his specimens is great, involving not only habitus and size of the interconular depressed areas, but the skeleton also. In the absence of more detailed structural data it is uncertain how far Hyatt was justified in grouping these forms together. With respect to some of them, varieties *typica*, *fixa*, and *felix*, his account intimates that the main fibers are fascicular, in the sense of being compound fibers. Lendenfeld (loc. cit., p. 561) refers others of Hyatt's specimens, var. *columnaris* to *H. variabilis*, evidently concluding (on what grounds is uncertain) that the main fibers in these are simple.

With respect to *H. campana*, we venture to say that possibly the vase shape is assumed by several West Indian Hircinias, or there may be a West Indian species (*H. campana*) which under certain conditions becomes vase shaped, but which may be of almost any habitus; in which the skeleton is very variable and imperfectly known; and in which the interconular areas vary greatly in size, from 2 to 10 millimeters in diameter; the species remaining recognizable in spite of its variability. Coues and Yarrow (1878) record under this name a specimen collected in the Beaufort region.

Schmidt (1870, p. 30) had also before him West Indian specimens which he identified as *H. campana*, but he frankly confesses that the wealth of Hircinia "forms" in the West Indian waters is so great that he can not divide them into species. This entanglement of "forms" still waits for its satisfactory analysis. Familiarity with considerable numbers of the living sponges in several localities and some breeding experiments are doubtless necessary for real success.

Lendenfeld (loc. cit., p. 569) classes *Spongia campana* as a Sarcotragus (=Hircinias with distinctly fascicular main fibers), and to this species assigns the vase shaped and flabellate sponges from the West Indies and Florida named *Polytherses campana* by Duchassaing and Michelotti (loc. cit.), *Hircinia campana* by Schmidt (loc. cit.), *H. campana* varieties *typica* and *fixa* by Hyatt (loc. cit.).

Discussion of the genus.—Lendenfeld in defining Hircinia (loc. cit., p. 545) lays stress, justly, we think, not only on the presence of filaments but on the way in which the connectives attach to the main fibers. He says: "The fascicular nature of the connecting fibers and their mode of attachment to the main fibers by numerous diverging roots, which extend in one plane, distinguish most species of Hircinia sufficiently from Stelospongia and from all other genera." He goes on to say that there are forms without this peculiarity, but these are plainly very close to the sponges with the peculiarity. Possibly this reasoning justifies Lendenfeld's inclusion under Hircinia of forms with dendritic fibers instead of a reticulate skeleton, such as *Cacospongia collectrix* Polejæff and *Oligoceras conulosum* Ridley.

The fascicular main fibers of Hircinia deserve a few words. They are structures that are somewhat vaguely treated in the literature and probably are not always understood in the same sense. The fact that the connectives are united to simple main fibers by diverging roots, which may extend in one plane along the fiber for a considerable distance, leads to the formation of a type of fascicular fiber different from that which is characteristic of Stelospongia (ante under description of this species). An examination of the literature indicates that it is widespread among the species now recorded under Hircinia. This type of fascicular fiber owes its existence, we believe, (1) to the extension of roots along the main fiber such that roots of successive connectives join one another, and (2) to the fact that several sets of roots which surround the main fiber at about one level but on different sides combine to form a close-meshed reticulum through the axis of which runs the original main (simple) fiber. The fascicular fibers appear to have this character in *H. favosa* and *H. fœtida* (Lendenfeld, loc. cit., pp. 571, 577), although Lendenfeld regards the fascicular fibers of this subgenus (Sarcotragus) as composed of several individual fibers joined at frequent intervals to one another (loc. cit., p. 533); that is, as compound fibers. But in *H. favosa* the sand grains are restricted to the most axial fiber of the fascicle, the whole structure appearing to consist of an axial fiber "surrounded by garlands of slender fibers" (loc. cit.). The structure appears to be the same in *H. fœtida*. Again, in describing the connectives of several species of subgenus Sarcotragus, Lendenfeld (p. 534) says the roots of the connectives "appear as continuations of the fibers which form the garlands in the main fascicles."

The size of the flagellated chambers has been adduced as a differential feature marking off Hircinia and Stelospongia (Lendenfeld, loc. cit., p. 484). The chambers are said to be larger in Stelospongia, the diameter being given as 41 to 48 μ. But in *Hircinia variabilis* F. E. Schulze, the diameter may be as much as 40 μ. In such a case this generic differential can not be applied, although it may hold for the majority of the species of the two genera.

The fundamental character of the fascicular fibers appears to be constant in Stelospongia. They are compound fibers (Lendenfeld, loc. cit., p. 478; Pl. XXXI, fig. 7; Pl. XXXII, figs. 7, 8, 9, 10). Lendenfeld sometimes calls them "plexus bands" (Pl. XXXI, figs. 4, 10, 12, 14; Pl. XXXII, figs. 9, 10). The constituent parallel fibers may be well apart, or may come together so closely as to fuse (Pl. XXXI, fig. 14). The width of the compound fiber thus varies greatly from less than 200 μ to several millimeters. It is unimportant whether the several main fibers of a "fascicle" arise as branches of a common fiber or not. Farther in the interior doubtless they often unite, although separate peripherally. Compound fibers of this kind, as we have seen, undoubtedly occur here and there in *Hircinia ectofibrosa*, but in this species certainly, and probably in the genus at large, when the main fibers become fascicular the characteristic formative method practiced is that of incorporating the roots of the connectives. The characteristic fascicular fibers of the two genera are thus probably quite different structures.

Since in Lendenfeld's system both under Hircinia and Stelospongia there are forms with single main fibers, *H. variabilis* and *S.* (*Cacospongia*) *vesiculifera*, for example, we are driven back in the separation of these forms, and hence in the separation of the genera, to the presence or absence of filaments and of "root plates" formed by the divergent roots of the connectives.

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EXPLANATION OF PLATES.

[Pls. LVI–LVX, from photographs; Pl. LXVI, from drawings.]

Plate LVI.

Fig. 1. *Poterion atlantica.* Vertical section, including cortex of outer surface and adjacent choanosome. × 21.

Fig. 2. *Cliona celata.* Section through oyster shell showing included sponge trabeculæ extending up beyond the surface in shape of oscular papilla, which is cut tangentially. × 15.

Fig. 3. *Spirastrella andrewsii.* Section vertical to the cloacal surface between oscula. × 15.

Fig. 4. *Cliona celata.* Pore papilla. Expanded cap is shown cut in vertical section. The section, below, is tangential and shows the surface of the wall of papilla. × 40.

Fig. 5. *Cliona celata.* On oyster shells. × 1.

Fig. 6. *Spirastrella andrewsii.* Side view of piece shown in fig. 7*b*. The dermal surface is at top of figure. Large incurrent canals, between which lie comparatively thin septa of sponge tissue, extend radially inward from dermal surface. × 1.

Fig. 7a. *Spirastrella andrewsii.* Small part of cloacal surface. Oscula contracted. × 1.

Fig. 7b. *Spirastrella andrewsii.* Small part of outer surface showing incurrent apertures. × 1.

Plate LVII.

Fig. 8. *Suberites undulatus.* Whole sponge, from the side. Base of sponge, to the left in the figure. × 1.

Fig. 9. *Suberites undulatus.* From a section showing fibrous skeleton of the interior. × 10.

Fig. 10. *Suberites undulatus.* Entire transverse section through a lobe. The dark patches in the choanosome represent the longitudinal skeletal fibers cut across. × 10.

Fig. 11. *Suberites undulatus.* From a transverse section through a lobe. Surface of sponge, above and to the left. × 15.

Fig. 12. *Reniera tubifera.* Dermal surface of an oscular tube. × 21.

Plate LVIII.

Fig. 13. *Stylotella heliophila.* Whole sponge. × 1.

Fig. 14. *Tetilla laminaris.* Side view of a small specimen. × ¾.

Fig. 15. *Reniera tubifera.* Whole sponge. × ¾.

Plate LIX.

Fig. 16. *Reniera tubifera.* Longitudinal section through a branch, including both surfaces. × 21.

Fig. 17. *Tetilla laminaris.* From a section vertical to one of the flat surfaces of the sponge. The long fiber in the interior ascends toward the upper edge of the sponge. × 15.

Fig. 18. *Stylotella heliophila.* Dermal membrane, in surface view. × 15.

Fig. 19. *Stylotella heliophila.* Section vertical to surface. × 21.

Plate LX.

Fig. 20. *Esperiopsis obliqua.* Biseriate habitus. × ½.

Fig. 21. *Esperiopsis obliqua.* Chaliniform habitus. Part of a macerated specimen, including the base. × ½.

Fig. 22. *Esperiopsis obliqua.* From a longitudinal section through a branch of the macerated specimen shown in Fig. 21. × 21.

Fig. 23. *Esperiopsis obliqua.* From a transverse section through a branch of the macerated specimen shown in Fig. 21. × 21.

PLATE LXI.

Fig. 24. *Phoriospongia osburnensis.* Sponge incrusting on alcyonarian. × 1.

Fig. 25. *Phoriospongia osburnensis.* From a section through the incrustation, vertical to the surface. Alcyonarian colony cut twice. × 28.

Fig. 26. *Lissodendoryx carolinensis.* Whole sponge. × ¾.

Fig. 27. *Lissodendorynx carolinensis.* Papilla. × 15.

Fig. 28.. *Lissodendoryx carolinensis.* Interior of sponge. From a section vertical to the surface. × 15.

PLATE LXII.

Fig. 29. *Phlœodictyon nodosum.* × 1.

Fig. 30. *Phlœodictyon nodosum.* Transverse section of a fistula. × 37.

Fig. 31. *Microciona prolifera.* From a longitudinal section through a branch of the sponge shown in fig. 35. × 50.

Fig. 32. *Phlœodictyon nodosum.* Ectosomal skeleton of fistular wall as seen in a surface preparation. Beneath the fine dermal reticulum appear the fibers. × 21.

Fig. 33. *Microciona prolifera.* From a transverse section through a branch of the sponge shown in Fig. 35. × 21.

Fig. 34. *Axinella acanthifera.* Whole sponge. × 1.

PLATE LXIII.

Fig. 35. *Microciona prolifera.* Older, branched, form. × 1.

Fig. 36. *Microciona prolifera.* Incrusting specimen, with lobes; on oyster shells. × 1.

Fig. 37 *Acanthella corrugata.* Whole sponge, viewed obliquely from above. × 1.

Fig. 38. *Axinella acanthifera.* Transverse section of lobe showing axial skeleton and radiating fibers. × 15.

Fig. 39. *Axinella acanthifera.* Longitudinal section through subcylindrical lobe, including both surfaces. × 21.

PLATE LXIV.

Fig. 40. *Pleraplysilla latens.* Thick section through the sponge, vertical to the surface. Only the more superficial part of the sponge appears distinctly. Three fibers are seen to terminate in conuli. The transparent area between two of the fibers is a large canal extending radially inward from just below the surface. The large flagellated chambers are shown. × 50.

Fig. 41. *Hircinia ectofibrosa.* Whole sponge. ×⅔.

Fig. 42. *Aplysilla longispina.* Part of the surface. ×1½.

Fig. 43. *Hircinia ectofibrosa.* Skeleton as seen in a macerated slice, vertical to the surface; principal fibers and connectives showing. The maceration was carried too far, and the superficial skeleton was injured. ×9.

Fig. 44. *Hircinia ectofibrosa.* From a section radial to the surface, showing a principal fiber with attached connectives. ×38.

PLATE LXV.

Fig. 45. *Aplysilla longispina.* Section vertical to the surface and through a conulus. A fiber is seen terminating in a conulus. The flagellated chambers are shown in the interior. ×21.

Fig. 46. *Acanthella corrugata.* Section vertical to the surface and radial to the margin; including margin and both surfaces of the sponge. ×21.

Fig. 47. *Acanthella corrugata.* From a section vertical to the surface and radial to the margin; below extreme marginal region. Mesial part of lamella and one surface are shown. ×21.

Fig. 48. *Aplysilla longispina.* Surface view of dermal membrane. Preparation photographed in water. ×21.

PLATE LXVI.

[All figures reduced in reproduction to one-third original size.]

Fig. 49. *Spirastrella andrewsii.* *a*, *b*, *c*, megascleres, ×385; *d*, spirasters, ×1,380.

Fig. 50. *Cliona celata.* Tylostyles. ×385.

Fig. 51. *Poterion atlantica.* *a*, *b*, *c*, tylostyles. ×385.

Fig. 52. *Suberites undulatus.* Tylostyles. ×385.

Fig. 53. *Stylotella heliophila.* *a*, *b*, *c*, styles. ×385.

Fig. 54. *Tetilla laminaris.* Spicules *a* to *g*, ×310; *h*, ×800; *a*, stouter form of skeletal oxea; *b*, long slender form of skeletal oxea; *c*, inequiended oxea of ectosomal brushes; *e*, stout protriæne of lower part of body; *f*, protriæne from oscular margin; *g*, hair-like protriæne of general surface; *h*, sigmata.

Fig. 55. *Reniera tubifera.* *a*, characteristic oxea and young stage; *b*, style; *c*, strongyle. ×640.

Fig. 56. *Acanthella corrugata.* *a*, style of the radial fibers, ×138; *b*, oxeote modifications of the same, ×138; *c*, *d*, *e*, megascleres with irregular ends, ×640.

Fig. 57. *Microciona prolifera.* *a*, *b*, skeletal styles, ×385; *c*, spinose styles, ×385; *d*, isochela, ×1,380; *e*, toxæ, ×1,380.

Fig. 58. *Esperiopsis obliqua.* Spicules *a* to *d*, × 640; *e* to *f*, × 1,380; *a*, smooth style; *b*, spinose style; *c*, strongyle; *d*, slender tylostyle; *e*, toxa; *f*, twisted isochelæ.

Fig. 59. *Axinella acanthifera.* *a*, style, common form; *b*, style, stouter form; *c*, style, longer slendered form, projecting at surface; *d*, spinose style. ×360.

Fig. 60. *Phoriospongia osburnensis.* *a*, strongyles, ×385; *b*, tridentate isochelæ in side, dorsal, and ventral views, ×1,380; *c*, sigmata, ×1,380.

Fig. 61. *Hircina ectofibrosa.* Ends of filaments. ×1,380.

Fig. 62. *Lissodendoryx carolinensis.* *a*, style, ×640; *b*, tylote, ×640; *c*, *d*, isochelæ in face and side views, ×1,380; *e*, sigmata, ×1,380.

Fig. 63. *Phloeodictyon nodosum.* Oxeas. ×640.

Fig. 64. *Aplysilla longispina.* *a*, simple skeletal fiber, ×138; *b*, upper end of dendritic fiber, ×138; *c*, dendritic skeletal fiber, including base of fiber and apex of one branch, ×138; *d*, part of fiber, showing pith, ×640.

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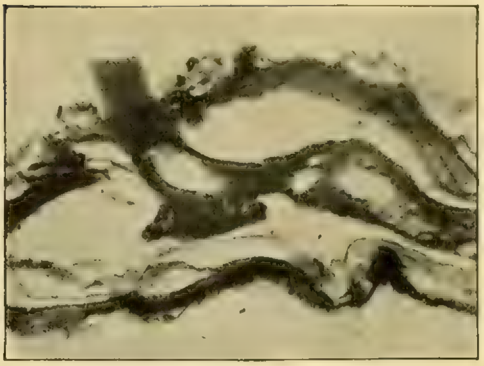

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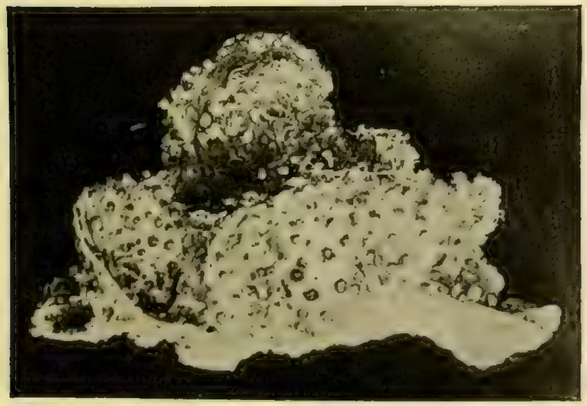

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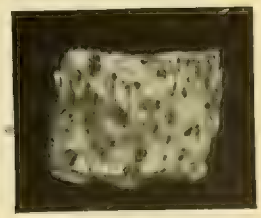

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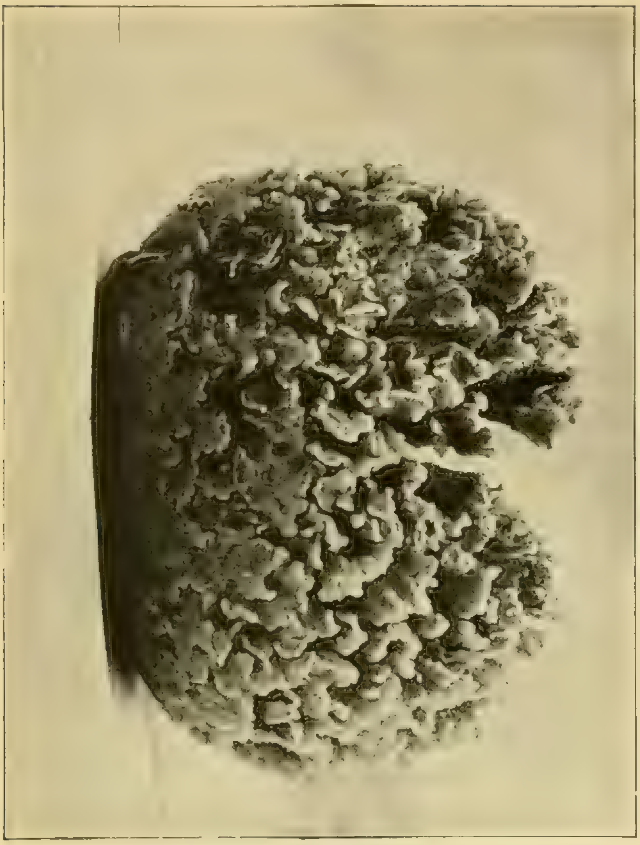

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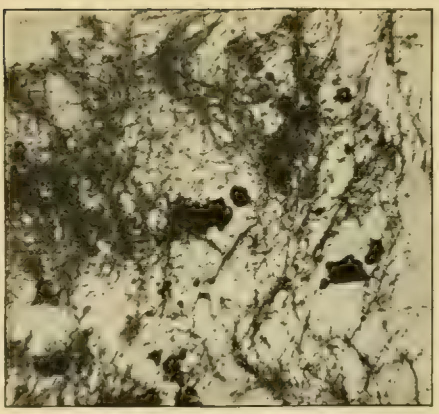

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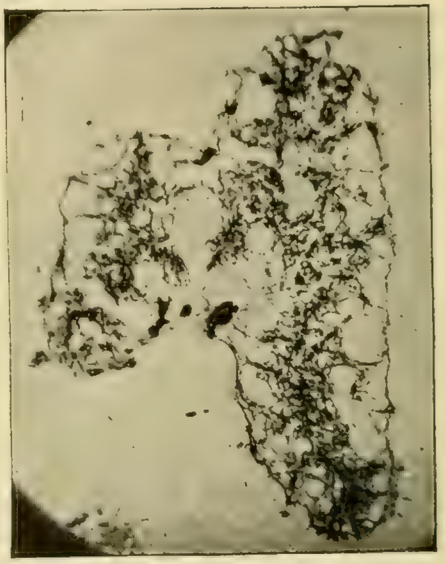

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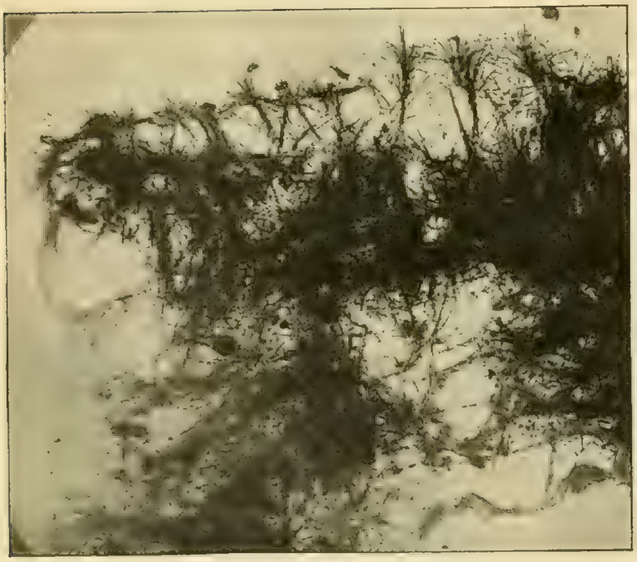

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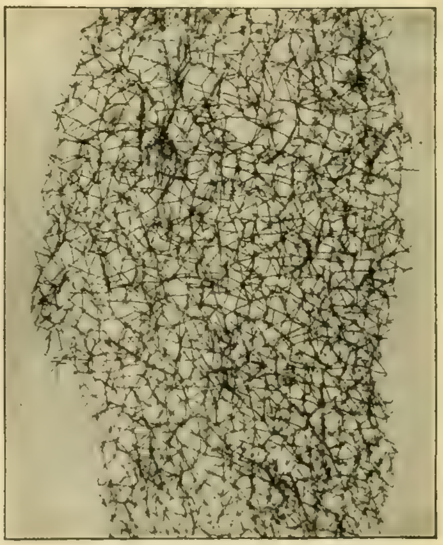

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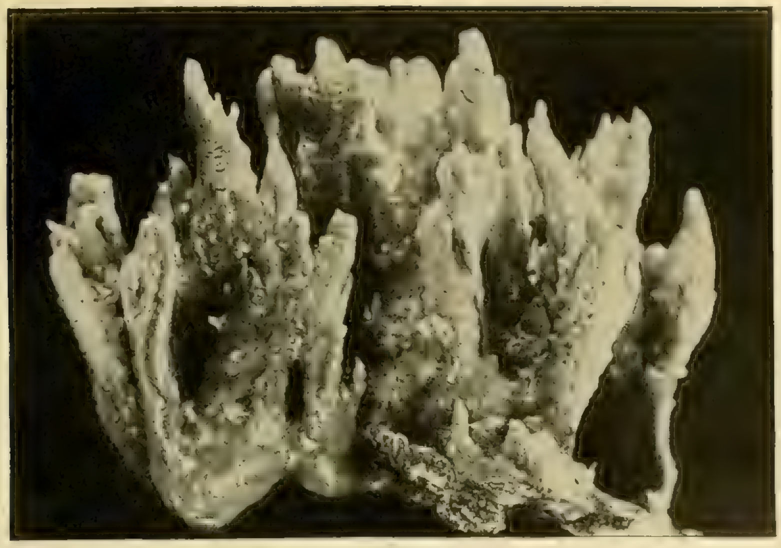

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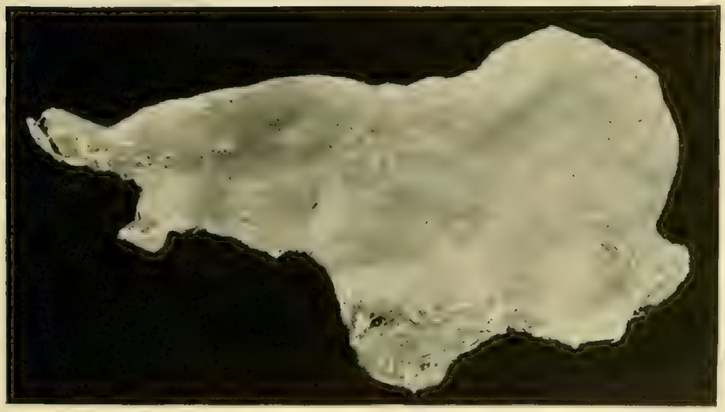

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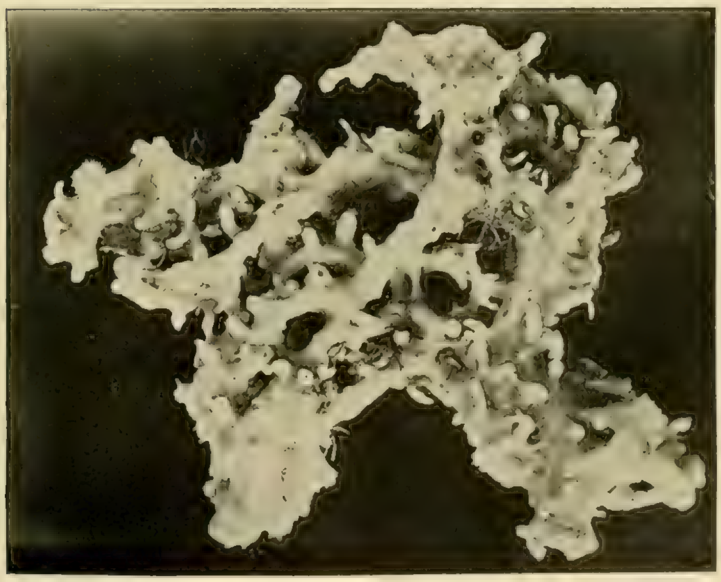

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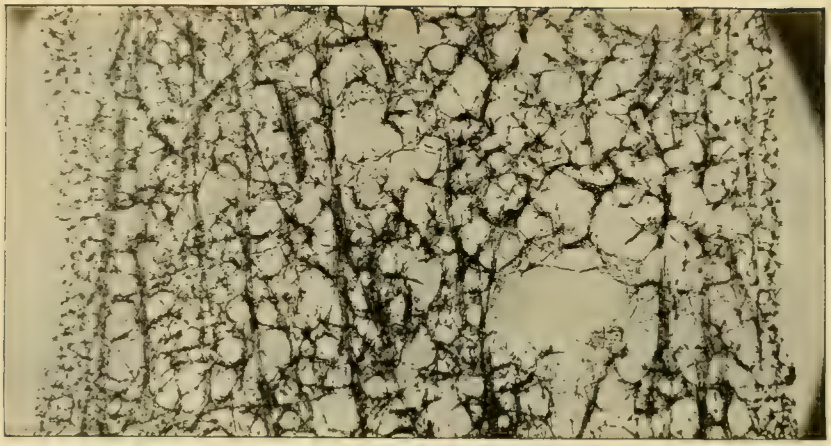

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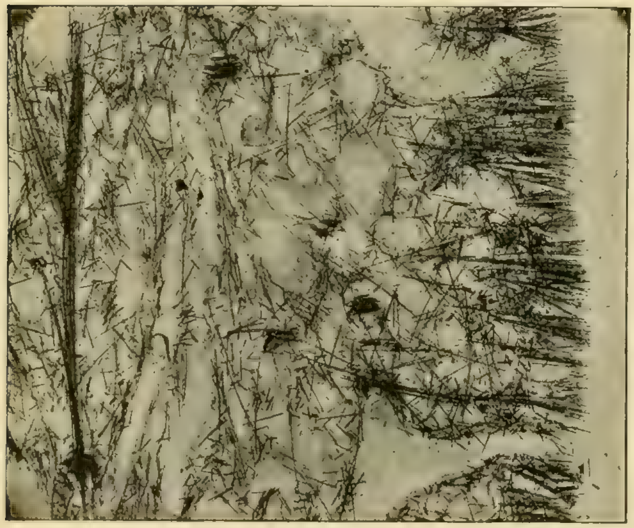

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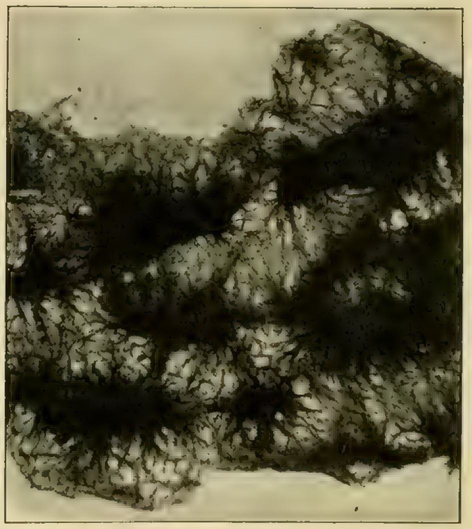

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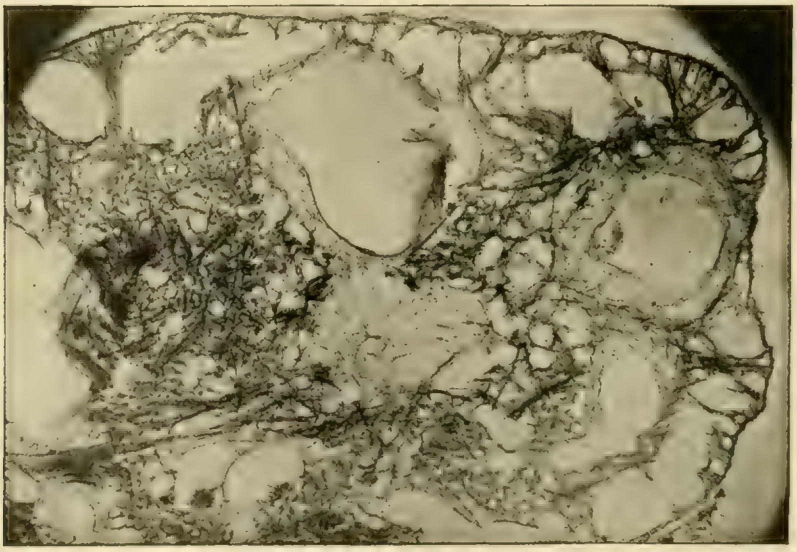

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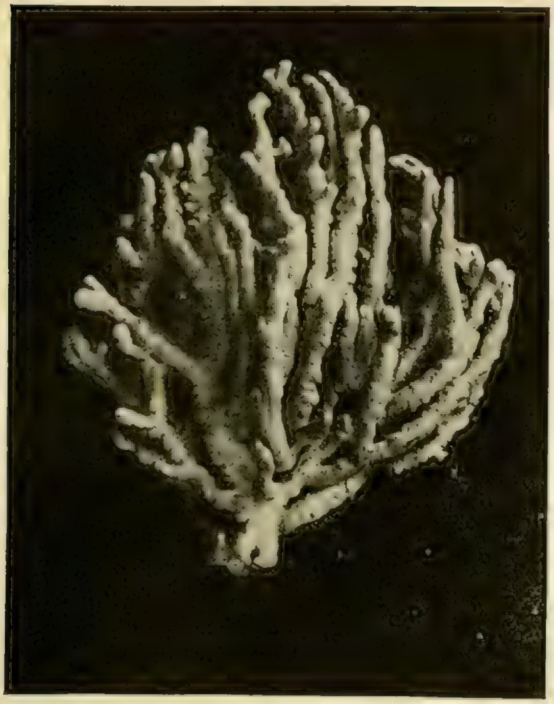

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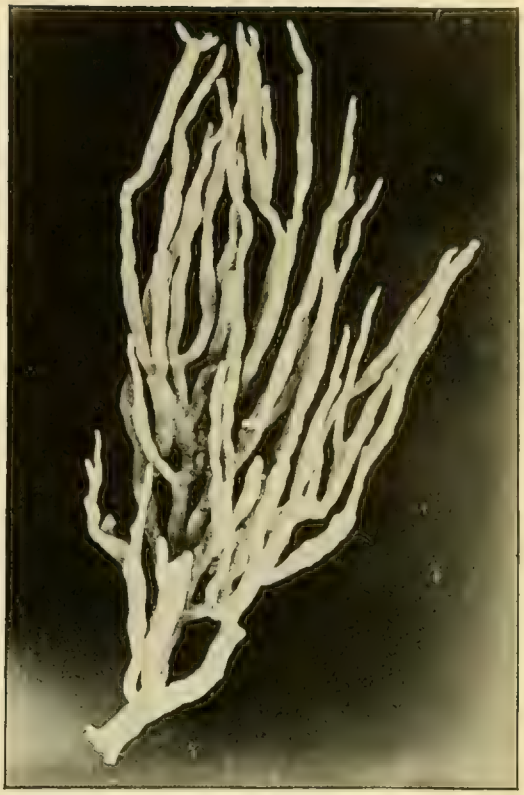

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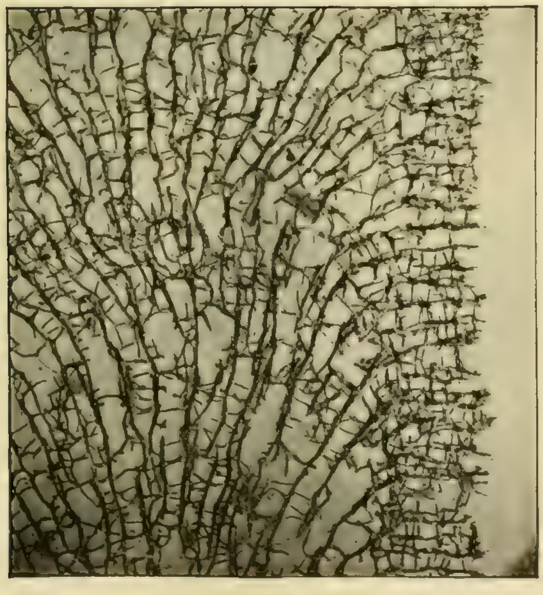

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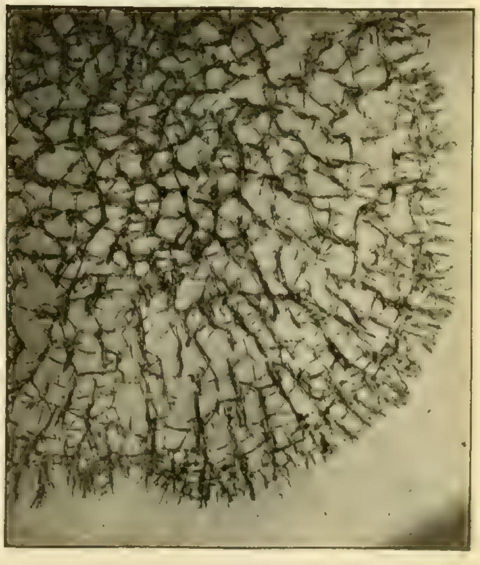

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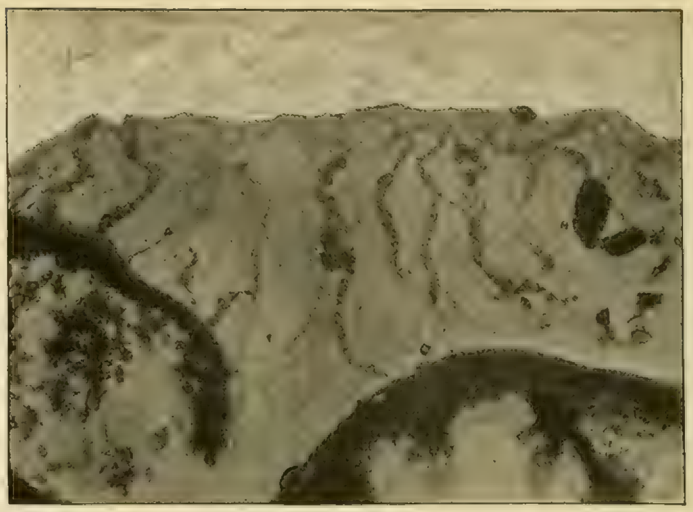

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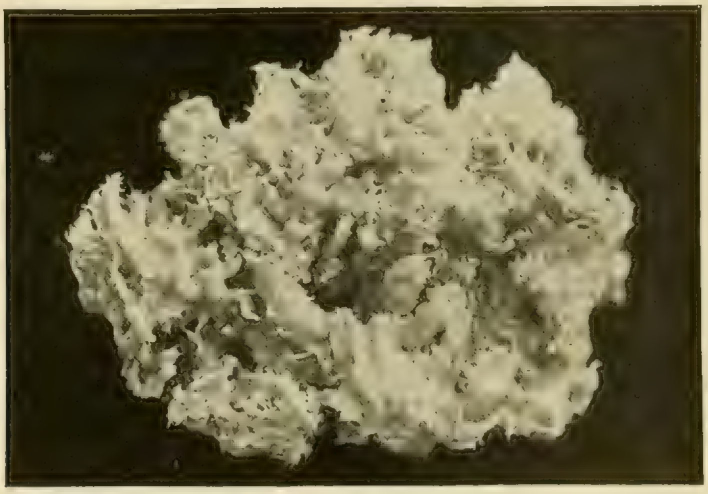

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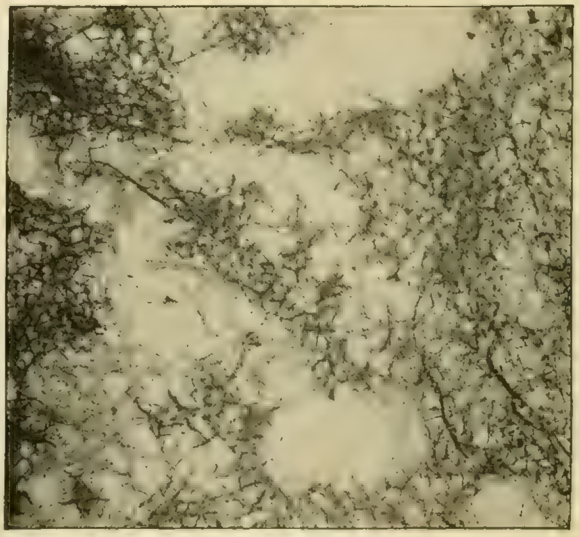

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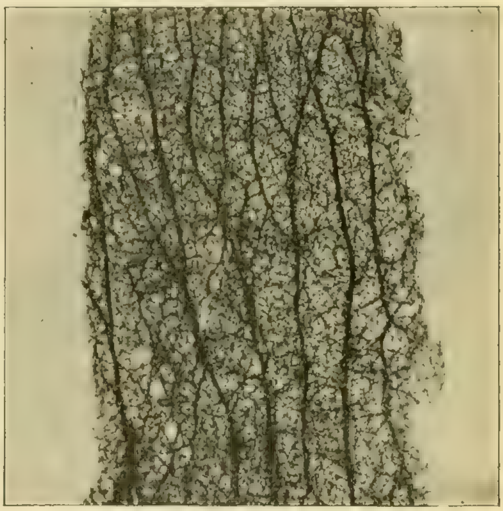

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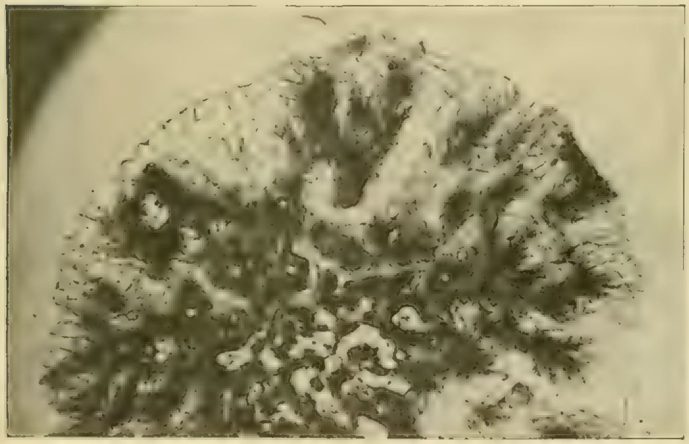

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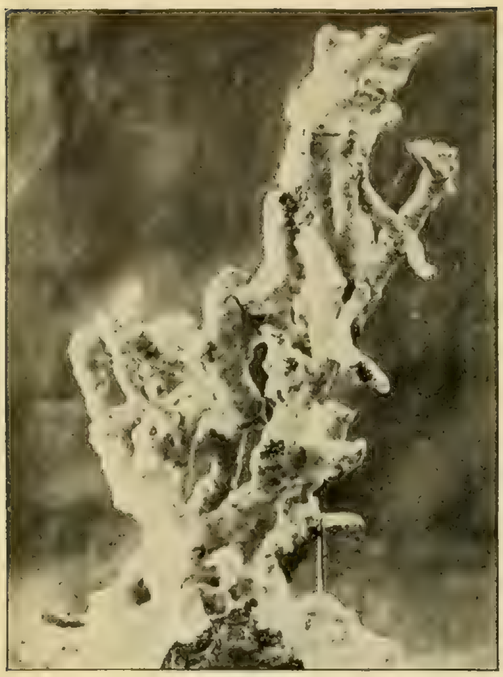

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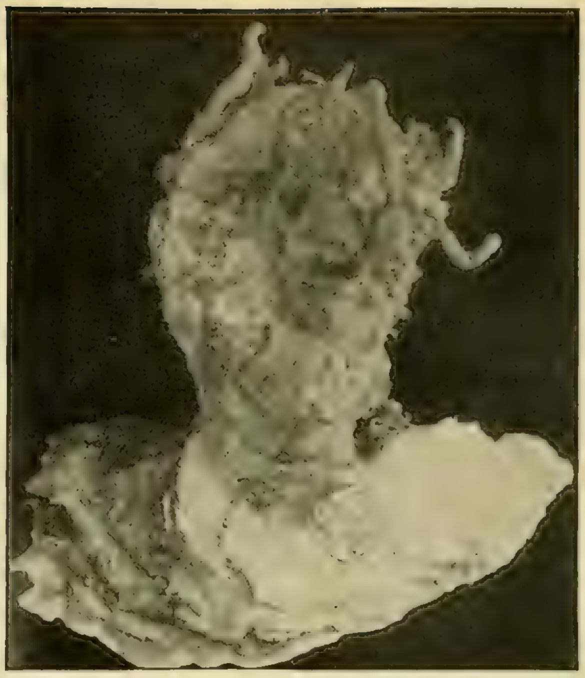

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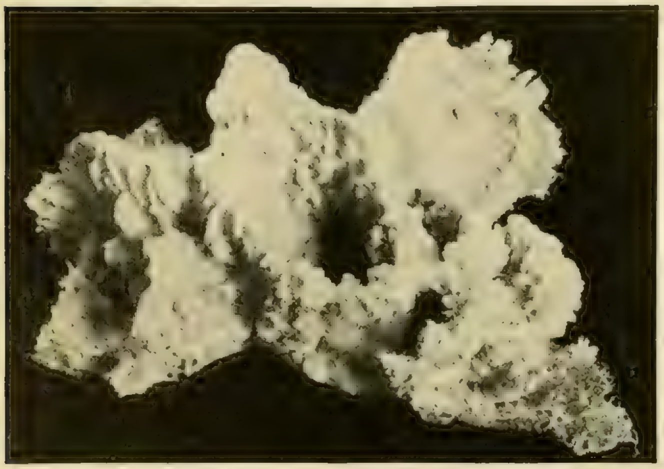

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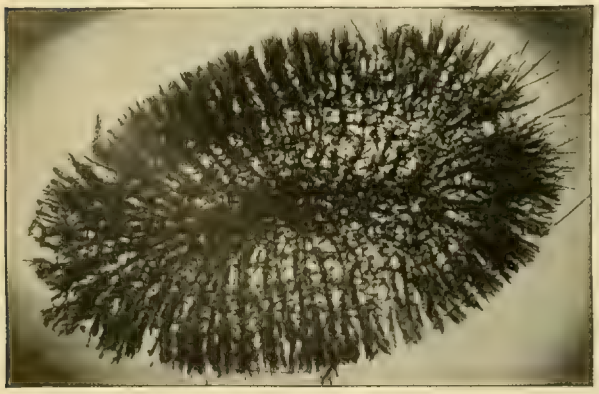

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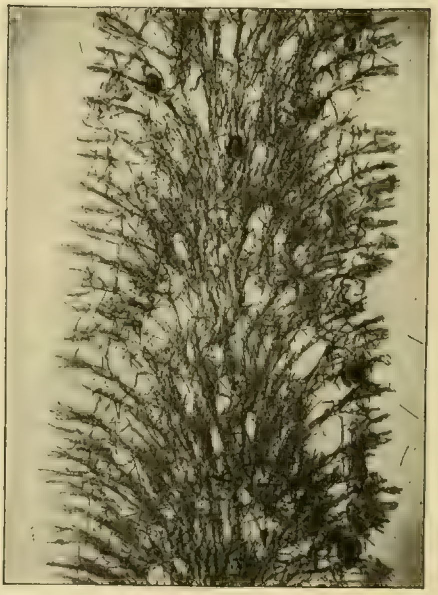

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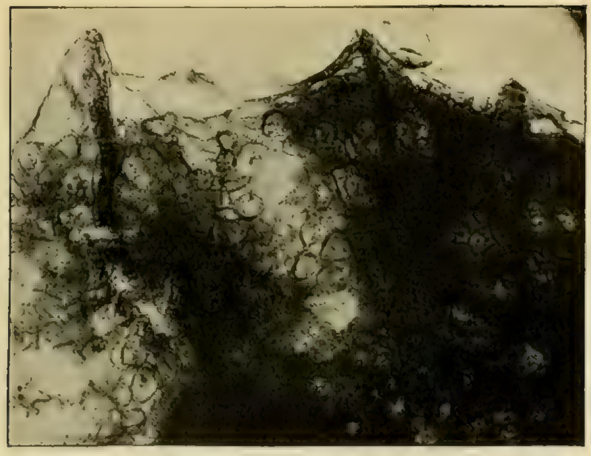

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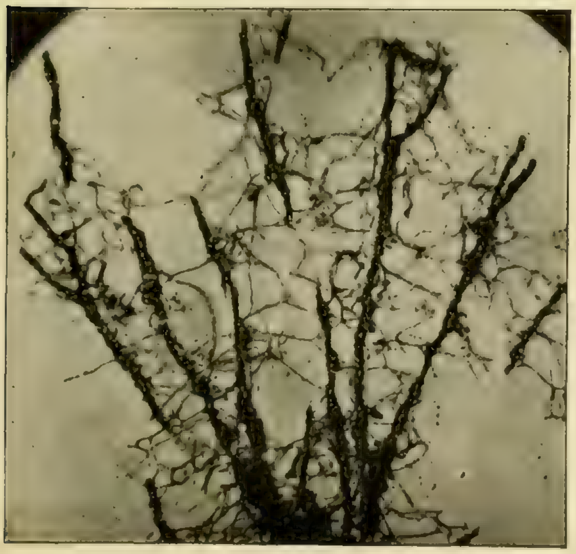

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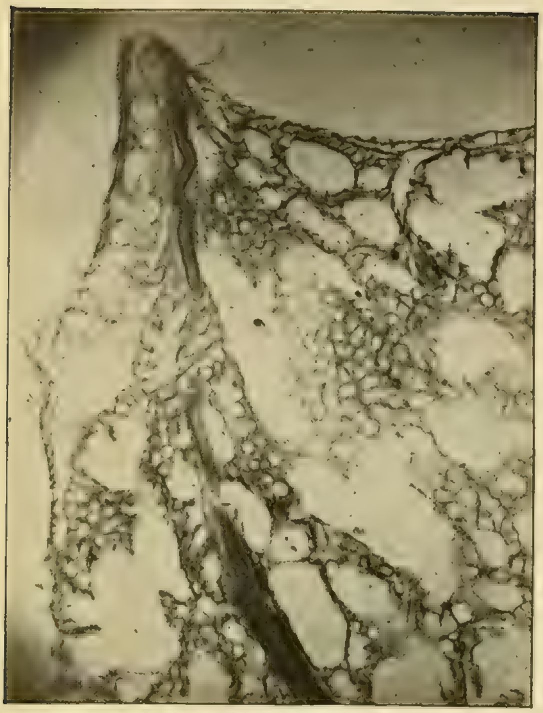

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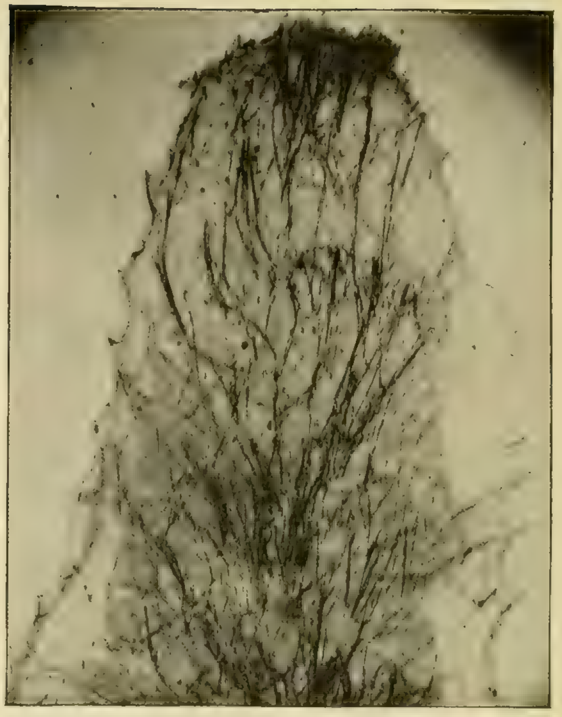

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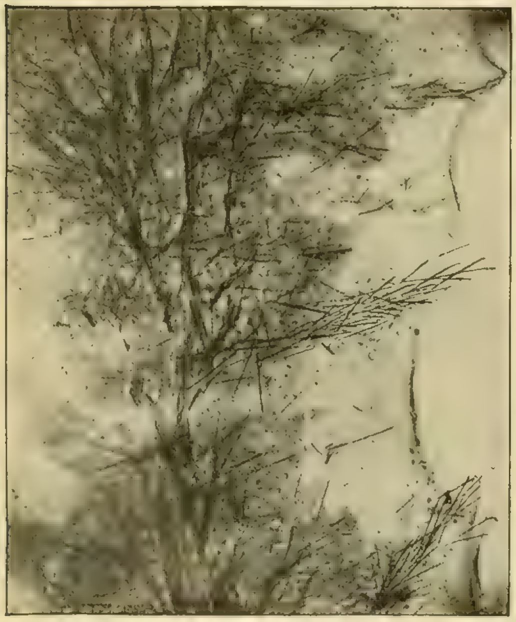

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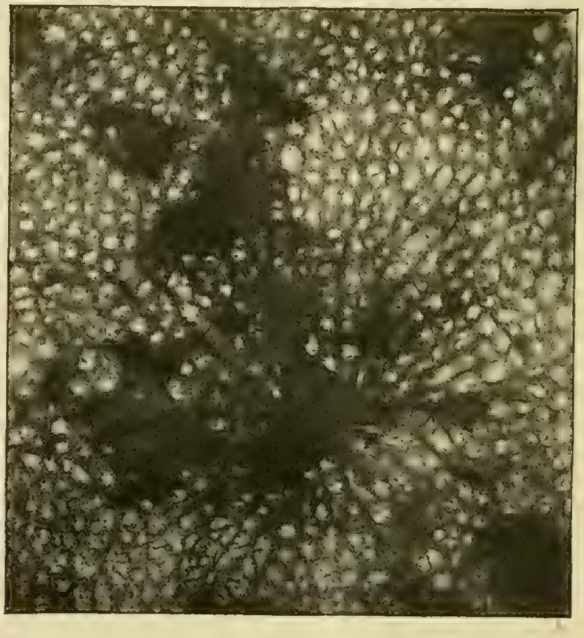

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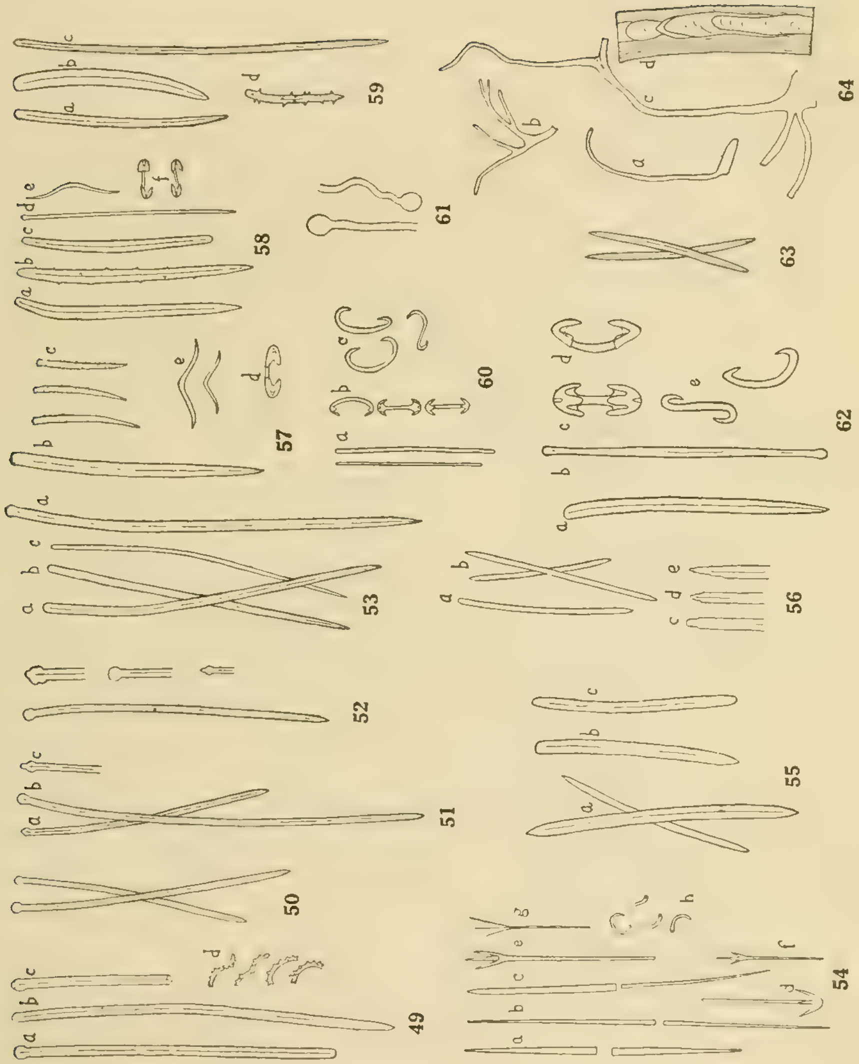
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DRAGONFLIES AND DAMSELFLIES IN RELATION TO PONDFISH CULTURE, WITH A LIST OF THOSE FOUND NEAR FAIRPORT, IOWA

⁂

By Charles Branch Wilson, Ph. D.
State Normal School, Department of Science, Westfield, Mass.

⁂

Contribution from the U. S. Fisheries Biological Station, Fairport, Iowa

FOREWORD.

The accompanying paper by Prof. Charles Branch Wilson, concerning a group of common insects in relation to fish culture, merits a special comment. The author has not confined himself to a mere list of dragonflies and damselflies or to the recording of observations regarding their distribution, abundance, habits, and life history. He has supplied such necessary information, but, more important from the point of view of the Bureau of Fisheries, he has treated these insects fully and judiciously in their relations to fish, and thus in their relations to the food supply and welfare of man.

We know that some insects, through destruction of crops and property or through injurious effect upon public health, are to be classed as insidious enemies of humanity and to be combated in every possible way; but there are others which we have learned to class as allies in the struggle for existence, since they make it possible for us to have useful articles of food and clothing, or are destructive to enemy insects.

There are many insects of several orders, including the dragonflies and damselflies, which, before they begin to fly, spend a long period of existence in the water where they have direct or indirect relations to the useful fishes. The attitude assumed toward any of these must depend on whether they are found to be useful or harmful to fishes and to man. The relations of insects and fishes are complex. Voracious insect larvæ may destroy the fry of fishes or may consume food otherwise available to young fishes; they may destroy other and more dangerous enemies of fishes; or they may feed upon things that are not available to the desirable fishes and themselves become food for fishes. It is necessary to accumulate exact information and wisely to balance the good against the evil before we can determine whether the abundance of any particular aquatic insect should be opposed or promoted in the interests of an increased food supply from fishes.

After a thorough analysis of all that has been known regarding the dragonflies and damselflies and all that has been learned in the course of this investigation, the author concludes with evident justification that these insects are, on the whole, of great economic importance, and he recommends them to the favor of the fish-culturist.

Studies such as this, which can be applied not only to other insects but to various kinds of aquatic animals and plants, will necessarily have the effect of enabling us to apply more intelligence to the practices of fish culture and the production of food from private and public waters.

H. M. Smith,
Commissioner of Fisheries.

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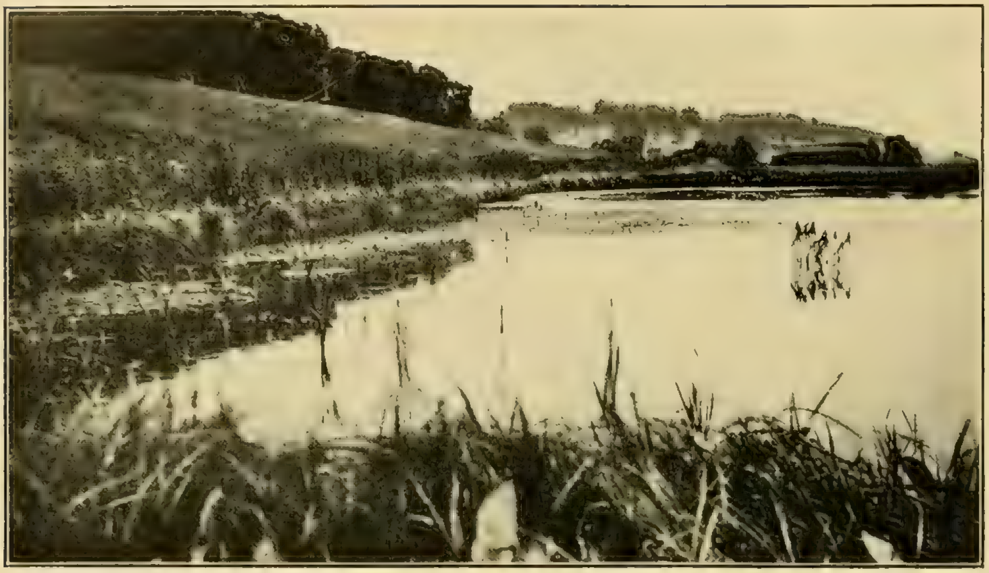


FIG. 1.—Pond No. 4, Series D, showing fringe of *Carex stricta* around the margin.

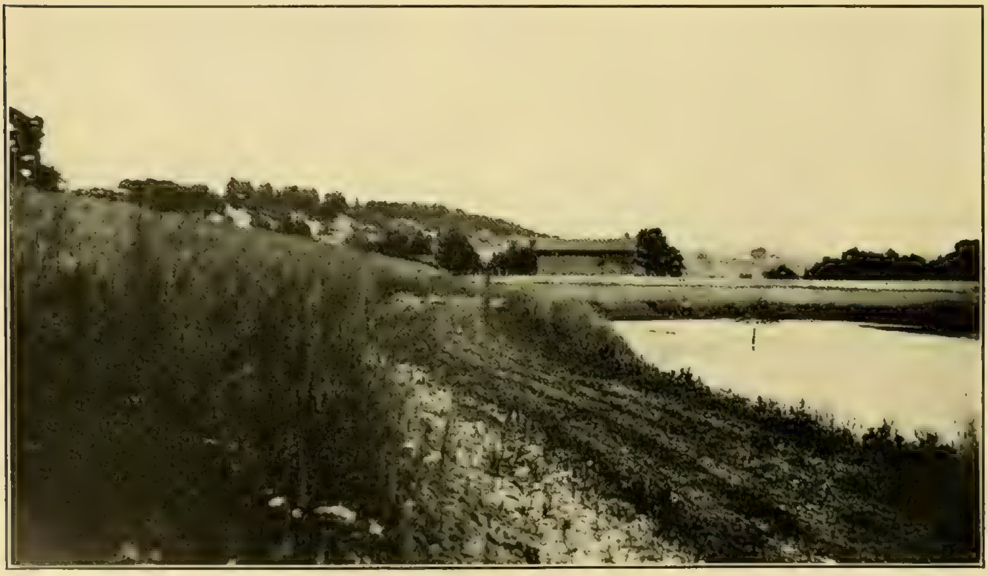


FIG. 2.—The cinder road along the north sides of ponds Nos. 1, 2, 3, and 4. To the left is seen the upland grass field which served as a roosting place at night for the dragonflies.

DRAGONFLIES AND DAMSELFLIES IN RELATION TO PONDFISH CULTURE, WITH A LIST OF THOSE FOUND NEAR FAIRPORT, IOWA.

By CHARLES BRANCH WILSON, Ph. D.

State Normal School, Department of Science, Westfield, Mass.

Contribution from the U. S. Fisheries Biological Station, Fairport, Iowa.

INTRODUCTION.

Among the various activities carried on by the Fairport Fisheries Biological Station is that of fish propagation, not the artificial rearing of fry and fingerlings for subsequent distribution, as usually carried on at a national or State fish hatchery, but rather the comprehensive and experimental breeding and rearing of adult food fishes in artificial ponds made for that purpose. Such intensive culture of food fishes bids fair to attract wide attention in the near future.

The Bureau of Fisheries has repeatedly called attention to the opportunities and possibilities of such culture, and recently the State colleges of agriculture have taken up the subject, led by the New York State College, at Cornell University. This latter institution published, August 15, 1915, a paper on "The Farm Fishpond," by George C. Embody (The Cornell Reading Courses, vol. 4, No. 94), in which are found the following statements: "Farm fish culture has been almost wholly neglected in America, even though a large part of the country possesses exceptional advantages for it. * * * During the past four years the New York State College of Agriculture at Cornell University has been giving instruction in the propagation of useful aquatic animals to a steadily increasing number of students. Letters are continually coming in from persons in different parts of this and other States seeking information concerning the propagation of frogs and fishes" (pp. 214 and 215). Much suitable instruction is then given, but very little is said with reference to environmental ecology.

In an article published in the Popular Science Monthly for July, 1915, Dr. R. E. Coker said: "The artificial propagation of fish, even under present conditions, is producing results of significant value, but it is no disparagement of such operations to venture the prediction that the future will show that the effective conservation of fishery resources depends upon the coupling of intelligent fish culture with comprehensive and well-advised conservation of the environment favorable both to the natural propagation of fish and to the multiplication of the essential elements of food supply" (p. 95).

The same author, in a later paper (1916, p. 402), while discussing the equipment, organization, and functions of the Fairport Fisheries Biological Station, said: "It is held as a most important responsibility of the station to stimulate and to guide the development of fish farming as a more widespread industry. This function as a fish-cultural experiment station should rightly be regarded as second to none."

On page 398 of the same report he stated: "It is manifest that the assembly of fish-cultural ponds, supplied originally with water from the Mississippi, but permitted to develop essentially pond conditions, stocked with abundant aquatic vegetation and rich in entomostraca, insect adults, and larvæ, together with the customary variety of smaller animal forms that thrive on the bottom, amidst the vegetation or in free-swimming condition, offer favorable opportunities for biological and physiological studies bearing upon problems of fish food, as well as for investigations of more particular scientific interest."

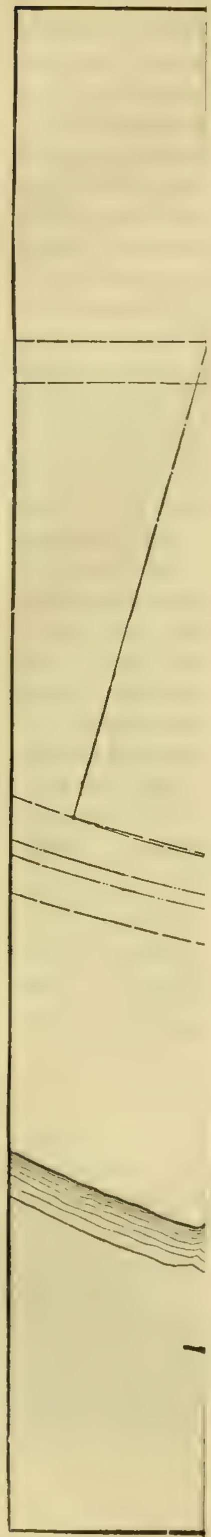
One feature of the environment, especially well developed at Fairport, and which will always be present in the pond culture of food fishes, is the presence of a greater or less number of dragonflies and damselflies which pass their larval life in the waters of the ponds and their adult life in the immediate vicinity. It becomes, therefore, of considerable importance to know whether the presence of these larvæ and adults is beneficial or injurious to the fishes. The ecology of this problem forms the main theme of the present paper, to which is added a list of such species as have been obtained at or near the station during three years of collecting.

The observations here recorded were made during the months of July and August, together with the last week in June and the first week in September. Some species emerge earlier in the year, but they usually have a second period of emergence within the limits just mentioned, and hence it is believed that the present observations cover all species of real importance.

GENERAL DESCRIPTION OF THE PONDS AND THEIR ENVIRONMENT.

The position and arrangement of the ponds of the Fairport station are clearly shown in the accompanying map. For convenience of manipulation they have been divided into six series called, respectively, A, B, C, D, E, and F, the ponds in each series being numbered independently. Series A and C are small cement ponds or out-of-doors aquaria for the temporary keeping of fish and mussels under experimentation and do not concern the present discussion at all. Series E and F are dirt ponds filled for the first time in July, 1916, and used the remainder of that summer and ever since. But owing to their newness when the present investigation on dragonflies and damselflies was begun, they were given no attention. During the summer of 1917, however, some of the observations on the food of odonate imagos were made around the shores of these ponds. Some of the young fishes also, the food contents of whose stomachs were examined during 1917, came from these ponds. This leaves only series B and D, the former south of the railroad and within 200 feet of the river bank, the latter north of the railroad and much farther from the river. Series B is made up of six small dirt ponds, the largest only 0.19 of an acre in extent, all of them heavily filled with algæ and water vegetation of various kinds.

Series D, on the other hand, contains nine large ponds with a total area of nearly 6 acres and presents admirable conditions for an ecological study of their environment. This is the series upon which the present study is based; they are all dirt ponds of the usual construction, having wide embankments thickly covered with vegetation, and



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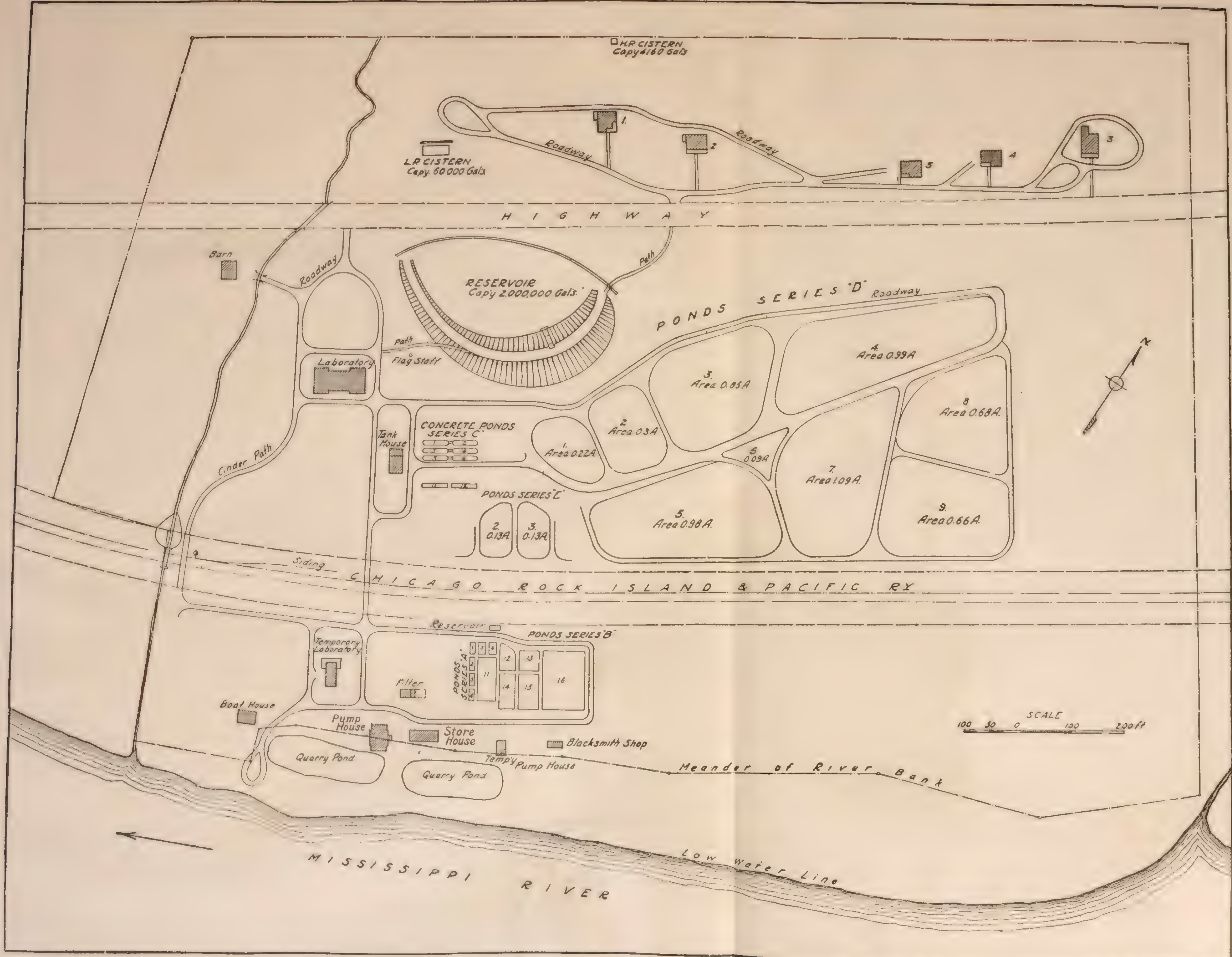

H.P. CISTERN
Capy 4160 Gals
L.P. CISTERN
Capy. 60,000 Gals
Roadway
Roadway
1.
2
3
4
5
HIGHWAY
Barn
Roadway
Path
RESERVOIR
Capy 2,000,000 Gals.
PONDS SERIES "D"
Roadway
Path
Flag Staff
Laboratory
Tank House
CONCRETE PONDS
SERIES "C"
1. Area 0.22A.
2. Area 0.3A.
3. Area 0.85A.
4. Area 0.99A.
5. Area 0.98A.
6. 0.09A.
7. Area 1.09A.
8. Area 0.68A.
9. Area 0.66A.
N
Cinder Path
PONDS SERIES "E"
2. 0.13A.
3. 0.13A.
Siding
CHICAGO ROCK ISLAND & PACIFIC RY.
Reservoir
PONDS SERIES "B"
Temporary Laboratory
Filter
PONDS SERIES "A"
11
12
13
14
15
16
Boat House
Pump House
Store House
Blacksmith Shop
Temp'y Pump House
Quarry Pond
Quarry Pond
Meander of River Bank
SCALE
100 50 0 100 200 ft
Low Water Line
MISSISSIPPI RIVER

United States Fisheries Biological Station, Fairport, Iowa.

each of them contains enough aquatic plants to make it very attractive to both dragonflies and damselflies. The distribution of fish and vegetation in and around these ponds is shown in the two tables which follow.

It may be noted that a heavy fringe of common crex grass, *Carex stricta*, has been planted at the water's edge around each of the ponds in order to prevent wave washing (Pl. LXVII, fig. 1). Ponds 1, 2, 3, and 7 are partially covered, at the proper season of the year, with a thick scum composed of the pollen of Philotria blossoms; ponds 4 and 8 show this scum in much smaller quantity, while it has not as yet appeared in the other ponds.

Along the north embankment of ponds 1, 2, 3 and 4 runs a cinder road (Pl. LXVII, fig. 2), to the north of which, away from the ponds, the land rises rapidly and was covered during the two summers of the present investigation with a heavy growth of grass, in which the dragonflies were accustomed to roost at night. This upland grass field up to the time of mowing was literally filled with odonate imagos, *Libellula luctuosa* being most numerous. Females could be found there at any time of day, and toward night or early in the morning, especially after a heavy dew, both sexes were present in large numbers. The algæ, pondweed, and rushes around these ponds furnish exactly the conditions favorable for odonate propagation, and, taken in connection with this ideal roosting place, with the constant supply of fresh water, and with the abundance of food, they present an exceptionally fine breeding ground for dragonflies and damselflies. This is shown not only by the comparatively large number of species found around these ponds but also by the extraordinary abundance of some of them.

To the south of the ponds along the railroad track is a ditch which always contains more or less water and which proves a favorite haunt for *Plathemis lydia*, *Anax junius*, *Libellula pulchella*, and *Pachydiplax longipennis*. There is a fringe of willows along the river bank opposite the ponds, and the slope of the terrace to the north of the dwelling houses beyond the highway is also wooded, but there are no trees or bushes anywhere in the vicinity of the ponds themselves.

The plankton of the ponds is very rich in entomostraca and other forms of life, and the water plants are covered with snails and insect larvæ of all kinds, furnishing a good food supply.

FISH DISTRIBUTION IN PONDS OF SERIES D, FAIRPORT, IOWA, 1916.

Species.	Pond numbers.								
	1	2	3	4	5	6	7	8	9
Micropterus salmoides: Largemouth black bass, adults	×	×	×			×			
Micropterus salmoides: Largemouth black bass, yearlings	×								
Micropterus dolomieu: Smallmouth black bass, adults						×			
Pomoxis sparoides: Black crappie, adults	×					×		×	
Pomoxis sparoides: Black crappie, yearlings	×								
Lepomis incisor: Bluegill, adults	×	×							
Lepomis incisor: Bluegill, 2-year olds	×								
Ictiobus cyprinella: Red-mouth buffalofish, adults				×					
Ictiobus bubalus: Smallmouth buffalofish, adults				×					
Ictiobus bubalus: Smallmouth buffalofish, yearlings					×				
Ictiobus bubalus: Smallmouth buffalofish, fry							×		
Lepomis gibbosus: Common sunfish, adults						×			
Lepomis euryorus: Wide-eared sunfish, adults								×	
Chænobryttus gulosus: Warmouth bass, adults								×	
Ictalurus punctatus: Channel catfish, adults									×
Ictalurus punctatus: Channel catfish, fry									×

PLANT DISTRIBUTION IN PONDS OF SERIES D, FAIRPORT, IOWA, 1916.

[a=abundant, c=common, s=scarce.]

Species.	Pond numbers.								
	1	2	3	4	5	6	7	8	9
IN THE WATER.									
Potamogeton illinolensis: Illinois pondweed	......	a	a	......	......	......	......	......	......
Potamogeton pusillus: Small pondweed	......	a	......	......	c	......	......	......	......
Potamogeton pectinatus: Fennel-leaved pondweed	......	......	a	......	......	s	......	a	......
Trypha latifolia: Cattail	a	a	a	......	......	......	s	......	s
Ceratophyllum demersum: Hornwort	s	c	c	s	s	......	c	s	c
Ranunculus aquatilis: Common water crowfoot	......	......	c	......	......	......	......	c	......
Oedogonium, sp.: Filamentous alga	c	......	c	......	......	......	c	......	......
Elodea canadensis: Water weed	a	a	a	s	......	......	a	c	......
Vallisneria spiralis: Eelgrass	......	......	c	......	......	s	......	s	......
Naias flexilis: Slender naias	s	s	s	s	s	s	s	s	......
Castalia odorata: White pond lily	......	......	c	......	......	......	......	......	......
Blanket algæ	a	a	c	a	a	a	c	a	a
ALONG THE MARGINS.									
Carex stricta: Crex grass	a	a	a	a	a	a	a	a	a
Rumex crispus: Curled sorrel	c	......	......	......	c	......	s	......	c
Eleocharis palustris: Creeping spike rush	s	......	......	c	c	c	......	......	s
Sagittaria latifolia: Broad-leaved arrowhead	......	c	c	s	......	......	......	......	......
Homalocenchrus oryzoides: Rice cut-grass	......	......	......	......	......	......	c	......	......
Juncus effusus: Common rush	......	......	......	s	......	......	s	......	s
Echinocloa crussgalli: Cockspur grass	......	s	......	......	a	......	s	......	a
ON THE EMBANKMENTS.									
Convolvulus sepium: Bindweed	c	......	c	s	......	c	......	......	s
Lactuca scariloa: Prickly lettuce	c	......	a	a	a	a	......	......	a
Equisetum fluviatile: Swamp horsetail	......	a	c	s	......	......	......	......	......
Trifolium pratense: Red clover	c	c	c	a	c	c	c	s	s
Plantago rugelii: Common plantain	a	a	a	a	c	c	c	s	s

ABUNDANCE OF DRAGONFLIES AND DAMSELFLIES.

The actual number of both dragonflies and damselflies varies greatly from time to time, due to a variety of causes.

1. PERIODICITY.—The emergence of the imago is periodic in occurrence; most of the Libellulidæ have a one-year cycle, and the great majority of any given species emerge at or near the same time. Just after this period of maximum emergence their numbers reach the highest point for the season, and then gradually decrease. Some species of Anax, Tramea, and Æschna may have two broods during the year, in spring or early summer, and again in late summer or early fall, and consequently would have two periods of maximum abundance. Even the Gomphidæ, whose nymphs require more than a year in which to mature, show similar periods of maximum emergence, large numbers being transformed within a few days and then diminishing rapidly in abundance. On the other hand, the damselflies apparently have several broods during the season, and their numbers rise and fall accordingly.

2. MIGRATION.—The imagos of many species have the habit of scattering rapidly soon after their emergence, even while they are still teneral, and they may sometimes entirely disappear. This is true of *Epicordulia princeps*, whose fresh nymph skins were second in abundance during the last of June, and yet not a single imago could be seen about the ponds at that time. The Gomphidæ furnish numerous similar examples; the most abundant of their nymph skins was that of *Gomphus plagiatus*, over a thousand of which were secured along the bank of the Mississippi opposite the ponds, but not a single

imago was found anywhere in the vicinity until the last of July, and then only a few. On the other hand, the imagos of both *Gomphus externus* and *G. vastus* were common about the ponds, but neither nymphs nor nymph skins were secured from the ponds themselves.

The nymphs of *Anax junius* and *Æschna constricta* were abundant in all the ponds, but comparatively few imagos could be found at any one time. This migratory scattering profoundly affects the numbers of imagos found about the ponds.

3. The Weather.—"All dragonflies are most active in hot, quiet, sunshiny weather" (Needham and Hart, 1901, p. 11), and consequently they appear more abundant at such times than on a dull, lowering day, when many remain in the shelter of the grass and weeds. Hence if we are to estimate the number of dragonflies correctly we must take into account the kind of weather during which the observation is made.

4. Concealment.—Large numbers of the smaller damselflies, especially such species as *Ischnura verticalis*, frequent the dense grass and are sure to escape observation. Hence the actual number of damselflies in any locality is almost certain to be underestimated, unless the grass and weeds are closely examined. A vigorous sweeping of the net over them always reveals far larger numbers than were first seen and often yields species that would otherwise escape detection.

Careful estimates, made by repeatedly walking around the ponds and counting such specimens as could be seen, making due allowance for repetitions and keeping in mind the considerations just presented, indicate that there is for each of the ponds a fairly constant average of 100 to 150 dragonflies, while the numbers of damselflies vary with their periods of emergence. Just after emergence there will be 300 to 500 for each pond, but between times the number may fall to 50 or even less. These numbers hold through the latter part of June, July, and the first of August, but become greatly reduced by the last of August.

RELATIVE ABUNDANCE OF DIFFERENT SPECIES.

Turning now to the relative abundance of the various species we can secure an exact numerical basis for our estimate. While it would be manifestly impossible to count the imagos of the different species and obtain any result worthy of record, good results can be obtained by gathering and counting the nymph skins. Such collections were made at intervals of two weeks during the summer of 1916 with the results shown in the following table. The successive counts were made along the north shores of ponds 4, 3, 2, and 1, respectively, the length of shore covered by each count being about the same. Over 2,000 nymph skins were obtained in the four counts, which indicates that the numbers given above under actual abundance are not too large.

NYMPH-SKIN COUNTS, PONDS 1 TO 4 D, FAIRPORT, IOWA, 1916.

Nymph skins obtained.	July 3.		July 16.		July 31.		Aug. 15.	
	No.	*P.ct.*	*No.*	*P.ct.*	*No.*	*P.ct.*	*No.*	*P.ct.*
Æschna constricta	1		2		30	5	20	4
Anax junius	2		10	2	46	7	48	10
Epicordulia princeps	31	6	1		12	2	15	3
Pantala flavescens					4		10	2
Tramea lacerata	2		3		4		40	8.5
Perithemis domitia			1		2		4	
Celithemis eponina	5	1	3		16	2.5	8	2
Leucorrhinia intacta	2		1		3		25	5
Sympetrum rubicundulum			10	2	12	2	26	5.5
Sympetrum corruptum	3		2					
Pachydiplax longipennis	1		6	1	51	8	20	4
Libellula luctuosa	442	89	310	66	246	40	137	29.5
Libellula pulchella	1		6	1	20	3	4	
Erythemis simplicicollis	2		114	24	160	26	112	24
Plathemis lydia	5	1			8	1		

Certain additional facts were noted during the gathering of the nymph skins.

1. CHOICE OF LOCALITY.—Upon reaching maturity the nymph does not crawl out of the water blindly wherever he may happen to be, but shows a definite preference for certain localities. Most of the nymphs here recorded transform in the early morning, at which time the west and north margins of the ponds receive the early sunshine, while the east and south margins are in the shade. It has been stated that the counts were made on the north shores; this was because those shores were found by actual trial to yield many more nymph skins than the east or south shores, and considerably more than the west shore. Another important reason is that the north shores border the shallower water of the ponds, and are thus naturally frequented by the nymphs when nearly ready for transformation.

A third factor which may influence the nymph in its choice of a locality for transformation is the kind of support obtainable. Some nymphs, such as those of *Libellula luctuosa*, Anax, and Epicordulia crawl up on anything that may be convenient, including wire screening, old boards, fence posts, and the like. Others show a decided preference for certain kinds of support and will even choose between different water plants. *Erythemis simplicicollis*, for example, selects the arrowleaf, *Sagittaria latifolia*, in preference to the cat-tail, *Trypha latifolia*, when the two are equally available. And this same species was the only one found in any abundance upon the stems of the crex grass, *Carex stricta*.

Erythemis transforms later in the day than many of the other species, and its exuviæ were found in large numbers along the eastern shores of the ponds. In five of the ponds these shores contain both cat-tails and arrowleaf in addition to the crex grass, but almost without exception the Erythemis nymphs had chosen the latter.

On the other hand, Anax usually emerges during the night, and its exuviæ were found upon the western and northern shores, and more of them upon the cat-tails than upon all other kinds of support combined. The large, sprawling nymphs of *Tramea lacerata* also take very kindly to the cat-tails, but shun the crex grass altogether.

Among the damselflies the Enallagmas are always found upon some convenient stem, a short distance above the water. Often there will be several exuviæ upon the same stem, and in one instance the number reached 21, as recorded upon page 230.

On the other hand, the nymphs of Ischnura very frequently crawl out upon the top of the lily pads and perch for transformation on the margin of the leaf, where it has curled up in the sun, half or three-fourths of an inch above the water. Twenty-five such teneral Ischnuras were seen close to their exuviæ upon the pond-lily leaves of pond 3 on the afternoon of July 28, 1917, but not a single Enallagma. Nor have the exuviæ of the latter ever been found in such places around the Fairport ponds.

The nymphs of *Argia mœsta putrida* often crawl long distances over the land and then up the trunk of a tree and are the only damselfly exuviæ found in such positions. This leads naturally to the second consideration.

2. Distance Traveled.—The distance to which the nymphs crawl before transforming varies greatly, not only for the different species, but also for different individuals of the same species. Some nymphs, like those of *Perithemis domitia* and the two Sympetrums, were always found upon rush or grass stems standing in the water, often at quite a distance from the shore. Others, like Anax, Æschna, and Erythemis, were close to the shore, sometimes over the water, and sometimes over the land, but never very far from the water's edge. *Libellula luctuosa*, Epicordulia, and Plathemis, on the other hand, crawl much farther and sometimes go a long distance. In the first count, 1 Plathemis, 5 Epicordulia, and 47 *L. luctuosa* crawled up the bank of the pond, across the cinder road, up a dirt bank bordering the road, and into the grass field, the entire distance being 50 or 60 feet. The other individuals of these species were all found between the road and the water's edge.

3. Lack of Protective Instinct.—While instinct may guide the nymph to the shallow and sunny side of the pond, it apparently fails him in some other directions. There were two red-winged blackbirds' nests in the cat-tails and crex grass on the shore of pond 2, where the second count was made. Twenty-five nymph skins were taken within a radius of 6 inches of one of these nests, three of which were actually fastened to the sides of the nest itself, and seven were found within a similar radius of the other nest. The young birds had only just left the nests and were still in the immediate vicinity, so that some of the nymphs must have transformed while the nests were still occupied.

4. Relative Abundance of Species.—From the counts above recorded it appears that *L. luctuosa* is the most abundant species, and also that it emerges before the others. Its time of greatest abundance is during the last of June and the first of July, when it constitutes over 90 per cent of the dragonfly fauna of the ponds. Although it keeps up a good percentage and remains throughout the season more numerous than any other single species, it quickly loses its relative predominance and steadily declines during the latter part of the season, until by the middle of August it is only a little more numerous than *E. simplicicollis.*

On the other hand the latter does not begin to appear until *luctuosa* has reached its maximum. It then rapidly increases, while *luctuosa* is decreasing, and its time of greatest abundance is the latter part of July, following which it declines through August.

Tramea, Anax, and Æeschna did not really begin to appear until the middle of July and then steadily increased through the remainder of the season, until by the first of September, together with Epicordulia, they were about the only species left. In 1917 a very much larger number of Anax and Æschna exuviæ were found early in the season, by the last of June or the first of July; but the imagos were no more numerous than during the preceding year, because they scatter immediately after emergence. Both species must return to deposit their eggs either in the pond where they were hatched or in some similar body of water. The Anax imagos are present in considerable numbers around the ponds by the first of August, and may be seen mating and ovipositing. The Æschna imagos delay much longer, and none have thus far been seen depositing eggs before the second week in September. In Massachusetts the same species, *constricta*, may be seen depositing its eggs as late as October.

Sympetrum corruptum appeared late in June and lasted for about three weeks and then entirely disappeared, its place being taken by *S. rubicundulum*, which remained the rest of the season.

Perithemis domitia was never present in sufficient numbers to really enter into the reckoning.

Plathemis lydia and *Libellula pulchella* were much more abundant in 1917 than in 1916, and both took an active part in the odonate life of the ponds. Previously they had remained quite constantly along the ditches beside the railroad tracks, but finally deserted them and assumed their appropriate places around the ponds.

LIFE HISTORY OF AN ODONATE.

In order to properly appreciate the relations between fish and dragonflies and damselflies it is well to consider briefly the life history of these insects.

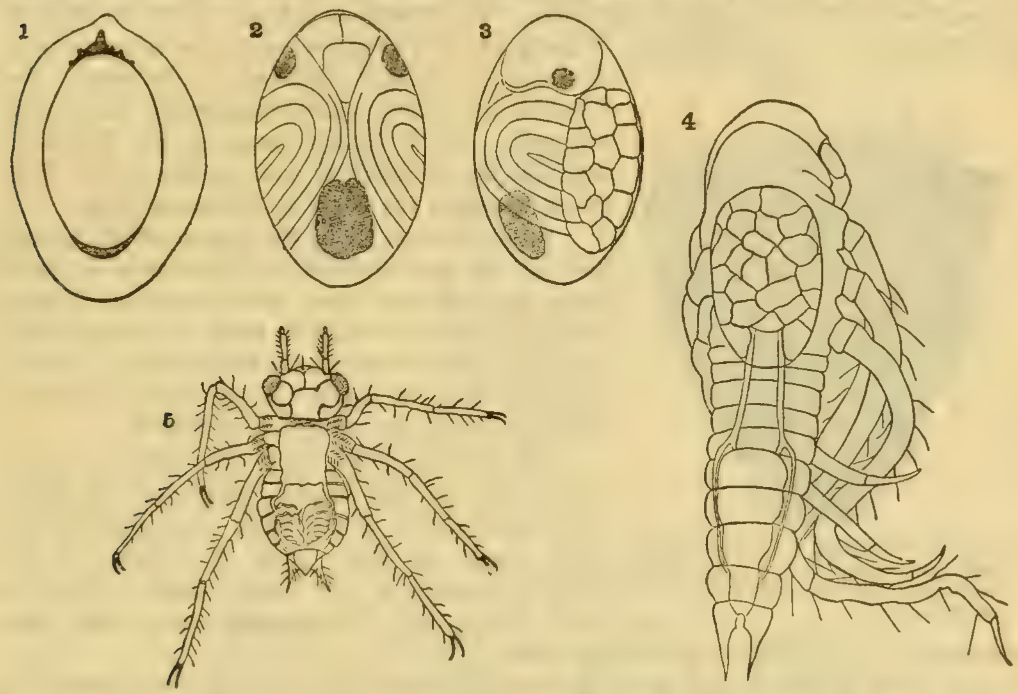
EGGS.—The eggs are laid in the water and hatch into larvæ called nymphs. The period of incubation varies greatly in different species; perhaps the average for dragonflies is from 5 to 10 days, and for damselflies about 20 days. Eggs laid by a Pachydiplax female and kept in the laboratory hatched in 5 days; Warren (1915, p. 8) also found the period of incubation in *Pantala flavescens* to be 5 days for two females and one male and 7 days for another male. The dragonfly's egg is ellipsoidal, narrowed a little at either end, and surrounded by a gelatinous envelope (fig. 1). There is a small projection or knob at the anterior end of the egg, which is known as the pedicel. It is formed of a thickening of the egg shell or chorion and furnishes the means by which the egg is attached to the egg string inside the ovary of the female.

The eggs of damselflies and of Anax, Æschna, and their relatives among the dragonflies are considerably elongated and assume a cylindrical form (fig. 58). The anterior end is pointed, with a short and wide pedicel, while the posterior end is bluntly rounded.

NYMPH.—At the end of the third day the larval pronymph could be seen inside the Pachydiplax egg and appeared as shown in figures 2 and 3, the long concentric lines being the folded legs. On emerging from the shell the pronymph is closely covered by a chitin sheath which holds the legs tightly to the body. It quickly molted out of this sheath and took the form shown in figure 5, but one was pulled out of the sheath before it had time to molt, and this one looked like figure 4. The body was elongate and fully segmented and the legs were more or less twisted from their previous folding. The pronymphal stage lasts usually but a very short time, less than a minute, sometimes only two or three seconds. The nymph, on the other hand, continues until it is ready to be transformed into the imago or perfect insect. Most nymphs require a year in which to fully mature; a few, like Gomphus, require more than a year, while others, like the damselflies Enallagma and Ischnura, may produce more than one brood in a season.

IMAGO.—In these latitudes the winter is passed in the nymph stage, and toward the close of the following spring the nymph, having passed through successive molts, is ready for transformation. This is accomplished by crawling out of the water onto some convenient object near at hand, to which it fastens with its claws. In a short time the skin splits across the top of the head and then along the back and the imago or perfect insect emerges, leaving the old nymph skin, called an exuvia, fastened to its support.

TENERAL.—After emerging, the imago is of a uniform pale yellow or tinged with blue, brown, or white, and it takes from a few hours to several days for it to acquire the bright colors of the mature adult. During this time it is called a teneral, its body is soft and flabby, its wings shine as if varnished, and its powers of flight are quite limited.



FIGS. 1 to 3.—The egg of *Pachydiplax longipennis:* 1, newly laid; 2, three days old, dorsal view; 3, three days old, side view, showing at the right the large ventral plate and in the center the folded legs. FIG. 4.—Pronymph of *Pachydiplax longipennis;* length, 0.90 mm. FIG. 5.—Nymph of *Pachydiplax longipennis* after the first moult; length, 1 mm.

PRUINOSE.—After becoming thoroughly hardened, some species, especially the males, are gradually covered with a bluish or whitish powder which may hide entirely the original bright colors; they are then said to be pruinose.

In *Plathemis lydia* the old males are almost white on the dorsal surface; in Erythemis and Pachydiplax they become blue; while in the damselfly, *Argia putrida,* the thorax and the last two segments of the abdomen appear to be blue, but this color disappears at once when they are put in alcohol.

MOUTH PARTS OF ODONATE NYMPHS.

DRAGONFLY NYMPHS.—In dealing with the food of nymphs and adults we need to know a little about the means which they possess for seizing, eating, and digesting their prey; let us begin with the mouth parts.

Mask.—The most noticeable thing about a nymph is the so-called mask, which is folded back beneath the head and which may or may not cover the lower part of the face (fig. 6), This mask is really the lower lip or labium, whose outer end terminates in three lobes, one median and two lateral; the latter may take the form of stout claws (Æschnidæ) or of spoon-shaped lamellæ (Libellulidæ). The mask is hinged near the center and when not in use is folded at the hinge; the lateral lobes are turned inward across the front end of the median lobe, and the whole apparatus is folded back beneath the head. Figure 7 is a side view of the head of *L. luctuosa*, showing the mask folded back, while the lateral lobes at its tip cover the lower half of the face. This is the condition found in the nymphs of all the Libellulidæ. Figure 9 is a side view of the head of *Anax junius;* here the lateral lobes do not cover the face at all, but extend straight forward as stout claws beneath the chin. This condition is found in the nymphs of the Æschnidæ, with the exception of the genus Cordulegaster, and as an accompanying character the head is depressed or flattened. The length of the labium varies considerably in different dragonflies, but is usually longer in the Æschnidæ than in the Libellulidæ and reaches back, when folded, between the bases of the second legs.

With the mask folded the nymph either conceals itself in the mud or trash on the bottom or steals up on its prey and when within striking distance shoots the mask forward in front of the head and grasps the victim between the lateral lobes. Figures 8 and 10 show the same two specimens of *luctuosa* and *junius* with the mask thus extended.

The distance which they can reach, of course, varies with the size of the nymph and the length of the mask; some of the large Anax nymphs can cover 15 to 25 mm. This, in addition to the lurching forward of the body, enables them to catch insects like Corixa, much more agile than themselves, and even to capture small fishes.

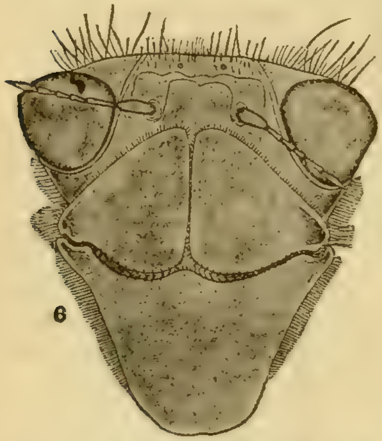

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FIG. 6.—Face of nymph of *Erythemis simplicicollis*, showing the large mask-like labium covering the lower part of the face up to the antennæ and eyes.

To assist in holding their prey, the lateral lobes of the mask are toothed along their inner margins in the Æschnidæ (fig. 11). In the Libellulidæ they are armed with a long, slender spine at the tip and a row or raptorial setæ behind this along the outer margin, varying in number in the different species. There is a crescent of similar setæ, also varying in number, along the body of the mask, called the mentum, on either side of the median line. And there are more or less regularly arranged spines and hairs along the remaining margins of all three lobes. Figures 12 to 14 illustrate some differences between the species.

Maxillæ.—Once grasped between the lobes of the mask, the prey is drawn quickly to the mouth, where there are two pairs of organs ready to dispose of it. The first of these, the outside pair, are the maxillæ, which are very much alike in all nymphs; each maxilla has two fingerlike branches or rami, the outer (ventral) of which is

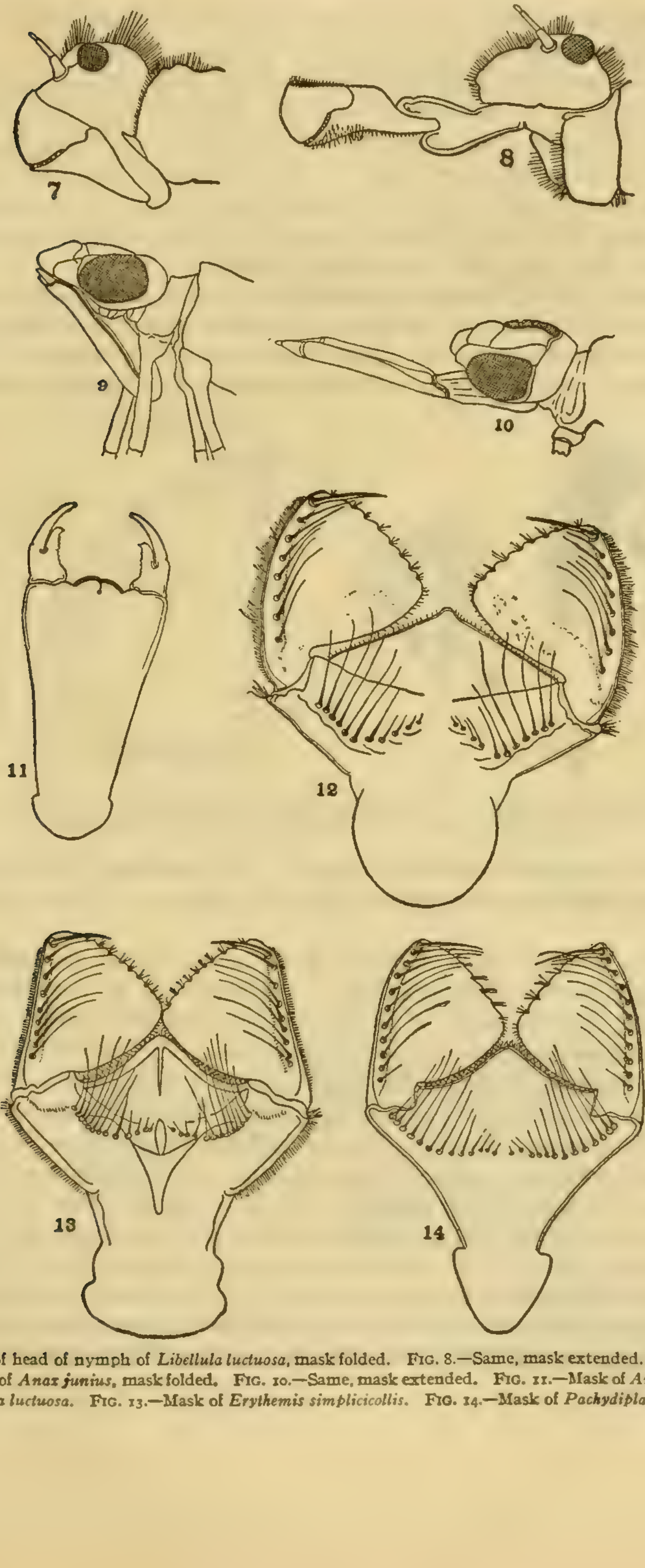

FIG. 7.—Side view of head of nymph of *Libellula luctuosa*, mask folded. FIG. 8.—Same, mask extended. FIG. 9.—Side view of head of nymph of *Anax junius*, mask folded. FIG. 10.—Same, mask extended. FIG. 11.—Mask of *Anax junius*. FIG. 12.—Mask of *Libellula luctuosa*. FIG. 13.—Mask of *Erythemis simplicicollis*. FIG. 14.—Mask of *Pachydiplax longipennis*.

armed with stout, curved claws, while the inner is covered with stiff hairs; these maxillæ are evidently used to help hold their prey securely (figs. 15 and 16).

Mandibles.—The second pair are the mandibles; they are much stouter, are hard and chitinous, and are armed with strong teeth (figs. 17 and 18). They can easily crush the shells of small pond snails like Limnea, Physa, and Planorbis, or they can bite through the hard chitin covering of beetles and water boatmen. The food contents of the stomachs of all the nymphs examined shows that the mandibles are used chiefly for crushing the food and not for chewing it. It is chewed only enough to get it down the gullet, and much of it is swallowed whole.

Gizzard teeth.—The real mastication takes place in the gizzard, and for this purpose the wall of the gizzard at the posterior end is armed with four longitudinal ridges of chitin—two dorsal and two ventral. Each ridge carries projecting teeth, whose number and arrangement varies a little in different species. The general character of these toothed ridges is well shown in figures 19 to 24. The churning of the gizzard grinds the food against the teeth and soon reduces it to finer fragments; it then passes on into the intestine.

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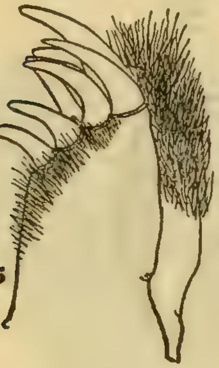

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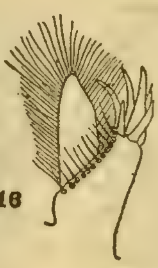

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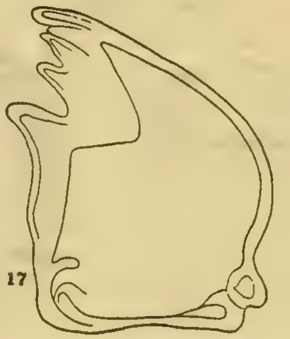

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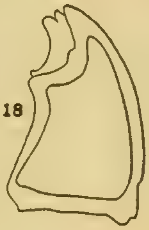
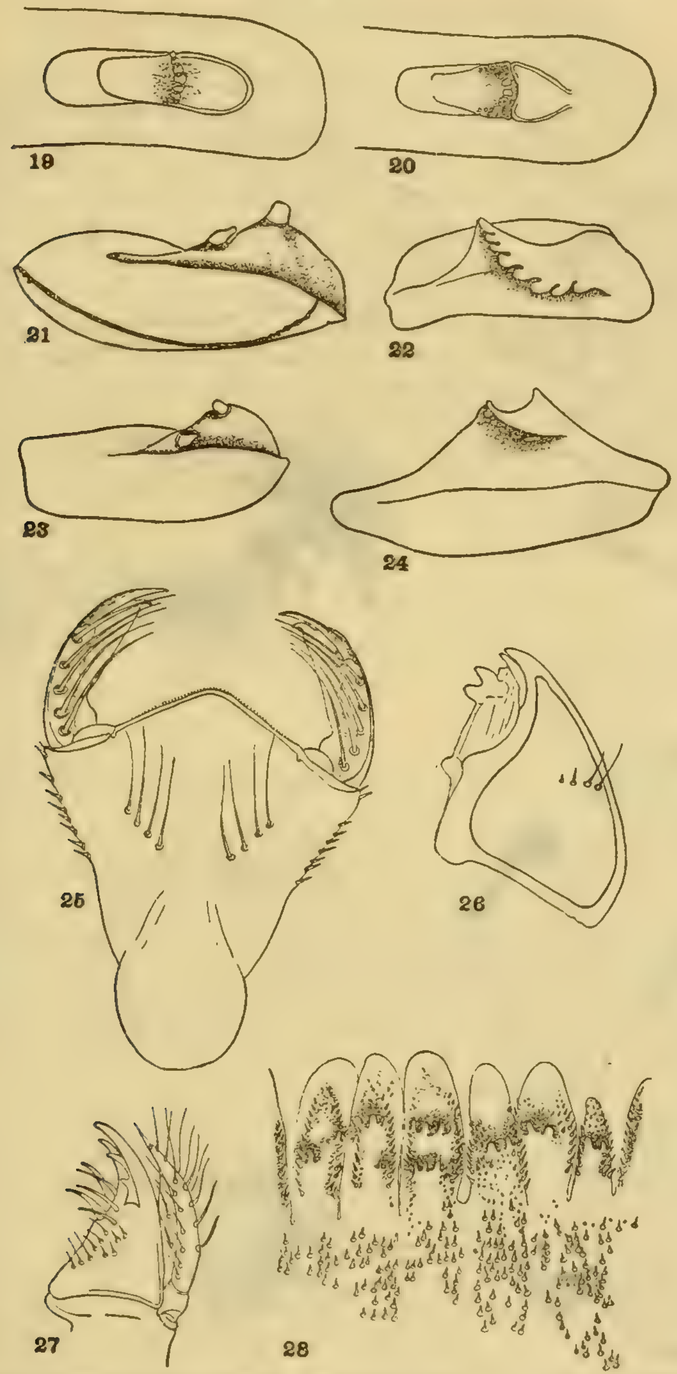
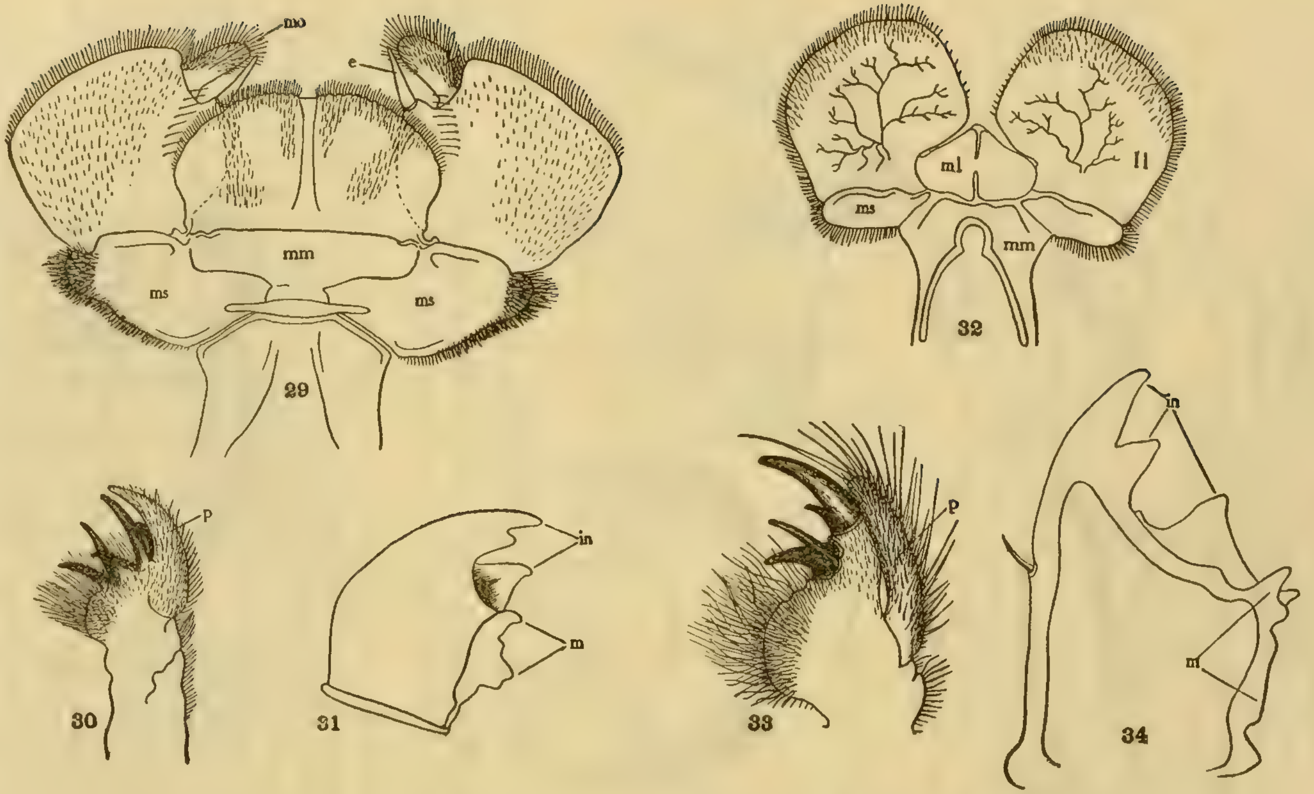


FIG. 15.—Maxilla of *Anax junius* nymph. FIG. 16.—Maxilla of *Erythemis simplicicollis* nymph. FIG. 17.—Mandible of *Anax junius* nymph. FIG. 18.—Mandible of *Erythemis simplicicollis* nymph.

DAMSELFLY NYMPHS.—The structure of the mouth of the damselfly nymph is in all respects similar to that of the dragonfly. The mask (fig. 25) is more like that of the Libellulidæ, with raptorial setæ on the lateral lobes and the mentum, but the lateral lobes only cover a very small portion of the lower face. The mandibles (fig. 26) and the maxillæ (fig. 27) are so much like the larger ones of the dragonflies that they can be recognized at once by comparison. In the gizzard we find a somewhat different arrangement; instead of 4 chitin ridges there is some multiple of 4 up to as many as 32, 8 and 16 being the most common numbers. Each ridge has a row of small spinelike teeth along the anterior half of both lateral margins; there is a narrow space through the center which is unarmed, and the whole posterior surface is covered with short stout spines, curved forward (fig. 28). Such a mill ought to be able to grind the food into very small fragments, and we find that this is actually done. In other damselflies the gizzard varies greatly both in the number of ridges and in the size and number of the teeth. The differences in the various genera and species have been admirably worked out and figured by Miss Higgins (1901).



FIGS. 19 and 20.—Dorsal and ventral tooth from gizzard of *Anax junius* nymph. FIGS. 21 and 22.—Dorsal and ventral tooth from gizzard of *Libellula luctuosa* nymph. FIGS. 23 and 24.—Dorsal and ventral tooth from gizzard of *Epicordulia princeps* nymph. Posterior end of each tooth toward the right. FIGS. 25 to 28.—Enallagma nymph: 25, mask; 26, mandible; 27, maxilla; 28, gizzard teeth, the upper edge of figure anterior.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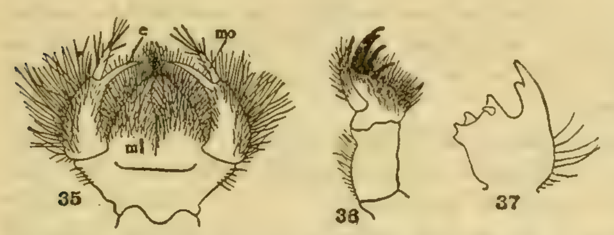
FIGS. 29 to 31.—Imago of *Anax junius:* 29, mask; 30, maxilla; 31, mandible. *e*, immovable end hook; *in*, incisors; *m*, molars; *mm*, mentum; *mo*, movable hook; *ms*, squame; *p*, palp. FIGS. 32 to 34.—Imago of *Erythemis simplicicolis:* 32, mask; 33, maxilla; 34, mandible. *ll*, lateral lobe of mask; *ml*, median lobe of mask; other letters same significance as above.

MOUTH PARTS OF ODONATE IMAGOS.

Dragonfly Imagos.—When the nymph transforms into an imago, the hinged mask disappears, and the labium or lower lip is now attached directly to the ventral surface of the head. In consequence there is a much greater similarity in the mouth parts of the imagos, though there are still some differences. In general, the labium of the imago consists of a basal portion, corresponding to the mentum of the nymphal mask, but destitute of raptorial setæ and very much shortened. From its anterior margin projects the median lobe, greatly enlarged in Anax and Æschna (fig. 29) and covered with hairs, but reduced to a small triangular piece in the Libellulids (fig. 32) and more or less free from hairs.

On either side of the mentum is a side piece known as the squame (ms) which supports the lateral lobe. These latter now fold together across the front of the face in all the imagos. In Anax and Æschna they are enlarged into concave lamellæ, strongly convex on their outer borders and covered with hairs. The inner border ends distally in a sharp end hook (e) which is immovable; just outside of this is a larger movable hook (mo), which is rounded and palplike and covered with hairs. When the lobes are folded across the front of the face, these four hooks meet on the median line, but the margins of the lobes beyond them diverge rapidly. In Erythemis (fig. 32) and the other Libellulids the margins of the lateral lobes, when folded, meet each other in a long median line, both hooks have practically entirely disappeared, and the lobes are covered with hairs. The mandibles (figs. 31 and 34) and the maxillæ (figs. 30 and 33) have changed a little in detail, but are practically the same as before. The teeth of the mandibles are very strong and may be divided into two sets, the incisors (in) at the tip of the mandible, which are long, curved, and sharply pointed, and the molars (m) near the base, which are much shorter and armed with separate cusps or points. The maxillæ still retain the outer lobe or palp (p), which is curved and covered with hairs, and the inner lobe, which is armed with curved and sharply pointed teeth and a pad covered with long sensory hairs.



Figs. 35 to 37.—Imago of *Enallagma hageni:* 35, mask: 36, maxilla: 37, mandible. *e*, end hook: *ml*, median lobe of labium: *mo*, movable hook.

Damselfly Imagos.—In the damselflies the general structure of the mouth parts is the same as in the dragon flies. Here the median lobe of the labium (ml, fig. 35) is fully as long as the lateral lobes, is divided by a deep median fissure, and is covered with long hairs. The lateral lobes retain the immovable end hook (e), which is very long and slender and curved to an acuminate point, and the movable hook (mo), which is also long and narrow, but is bluntly rounded and covered with hairs. These lobes are relatively much narrower than those of the dragonflies, and, when folded, only the terminal hooks meet on the median line. The mandibles (fig. 36) and maxillæ (fig. 37) are similar in all respects to those of the dragonflies, except that there is a sharper distinction between the incisors and the molar in the mandibles, while the maxillæ have long hairs on the outer margin near the base.

The gizzard in the imago is relatively much smaller and weaker in the nymph, and has very little functional use. The chitin ridges or folds along its walls are still retained, but the teeth are either completely lost, as in the dragonflies and in Lestes among the damselflies, or they are reduced to a much simpler form. The imago evidently chews its food before swallowing it, as we may well believe after watching one munch its prey.

This brief description of the mouth parts of the nymphs and imagos will enable us to understand better both how they secure their prey and how they dispose of it afterwards.

ECONOMIC RELATIONS BETWEEN ODONATES AND FISHES.

The artificial propagation of fish falls very naturally into three great divisions: 1. Suitable methods of obtaining and hatching the eggs; 2. Care and protection of the young after they are hatched; 3. Provision of an abundance of the right kind of food.

Our national and State fish hatcheries are concerned very largely with the first two of these, and the progress they have achieved is marvelous, considering the difficulties surmounted. In a comparatively brief period of years they have accumulated a wealth of accurate information and statistics, which have attracted the attention and awakened the admiration of the entire world.

But the last factor, in so far as it concerns pond fishes, has thus far received almost no attention in this country. Europe has been studying the problems connected with fishponds for many years and has far outstripped us along these lines. In fact, we have made hardly a beginning as yet, and the few facts that have been ascertained still lack correlation and logical arrangement.

In speaking of the food relations of insects and fishes Needham (1901, p. 395) said: "And so little are the essential features of good foraging ground understood that each planting of fry in a new place is still largely an experiment. * * * Any new study of fish food should include the study of the feeding grounds, feeding habits, choice of food offered, and conditions that make for the continuance and possible increase of the food supply." In spite of the 15 years that have elapsed since then, the statement retains practically its full value to-day.

Prof. S. A. Forbes and his associates in Illinois were pioneers in this aspect of fish culture, and have put out much valuable information on the food of fresh-water fishes during the last 35 years; an admirable summary will be found in Forbes, 1888*b*. More recently papers have been published by L. L. Dyche, 1914; Wm. E. Meehan, 1913; A. S. Pearse, 1915; Geo. C. Embody, 1915, and Dr. Robert E. Coker, 1915.

These papers are all excellent in both their subject and its treatment, but of necessity they are general in character and do not treat any of the phases in detail. For this reason and for many others it is believed that a summary of the economic relations between odonates and fishes will prove of interest to all who are, and especially to those who may become, engaged in pondfish culture. At present the old idea prevails that the nymphs of the Odonata, especially those of Anax, Æschna, and other large species, are very destructive to small fishes.

So far as known, the other side of the question has never been presented, and we have not only drawn a one-sided and biased conclusion, but we have also been led into the common error of condemning the many for the sins of the few. A hawk steals a farmer's chicken, and immediately all hawks are condemned as pests and robbers, irrespective of species, and a loaded shotgun is kept for their reception. Similarly because Anax and Æschna nymphs have been known to kill small fish, all dragonfly nymphs have been condemned as nuisances and dangerous to have around a fishpond.

Such a conclusion is, of course, not warranted, and even with reference to Æschna itself it does not follow that it must be considered dangerous simply because it eats a few small fish. Needham (1903, p. 213), one of our most experienced observers, said with reference to *Æschna constricta*, which was common at Bone Pond, one of the three propagating ponds controlled by the Adirondack hatchery in New York, and artificially stocked with brook trout: "I have not been able to determine as yet whether in relation to trout culture Æschna is more disadvantageous than otherwise. It eats a few fry and it eats the food of the larger trout, but, on the other hand, it furnishes a moderate supply of food itself for the larger trout." In order to solve such a problem satisfactorily we must consider in detail all phases of the economic relations between odonates and fishes. An endeavor to do this has been made in the following pages by a careful consideration of the food and enemies of dragonfly and damselfly nymphs and imagos, by a summary of all that is known of nymphs and imagos as fish food, and by extensive observation and experimenting.

FOOD OF ODONATE NYMPHS.

The alimentary canals of 50 nymphs of each of the four dragonflies enumerated in the following table and 50 others of various damselfly species, making 250 in all, were examined to ascertain what food had been eaten. The presence in a nymph's digestive tract of any of the various kinds of food listed was represented by a single unit, whether found in large or small quantities. The figures in the table, therefore, tell us how many of the nymphs had eaten any specified food, but do not indicate how much they had consumed.

FOOD OF 250 ODONATE NYMPHS FROM FAIRPORT, IOWA.

[The figures indicate the number of nymphs in which each kind of food was found.]

Contents of alimentary canal.	Anax junius.	Libellula luctuosa.	Erythemis simplicicollis.	Pachydiplax longipennis.	Damselfly nymphs.
Mollusca:					
Physa shells, mostly fragments	16	6	16	4	8
Planorbis shells, mostly fragments	15	34	22	4	12
Beetles:					
Dytiscus larvæ	10	8	2	2	....
Haliplid beetle, elytra of adults	8	3	8	12	....
Peltodyes larvæ, jointed hairs	....	7	6	....	....
Diptera:					
Ceratopogon larvæ	2	3	6	....	2
Chironomid larvæ	....	....	5	3	8
Mosquito larvæ	....	1	....	1	6
Simulid larvæ	....	....	8	4	9
Hemiptera: Corixa, sp., elytra of adult	14	4	3	1	....
Sialidæ: Sialid larvæ	3	....	2	....	....
Perlidæ: Stonefly larvæ	....	2	6	2	....
Ephemeridæ: Mayfly larvæ	27	9	7	4	6
Crustacea:					
Entomostraca, fragments unidentified	5	21	26	15	20
Cladoceran eggs, with ephippium	2	7	9	6	10
Bosmina, sp	3	8	6	4	12
Cypris, sp	6	35	2	20	15
Crustacea—Continued.					
Simocephalus, sp	5	2	2	4	8
Daphnia, sp	2	....	....	4	17
Pleuroxus, sp	....	....	3	5	5
Copepods, fragments unidentified	2	2	4	14	15
Diaptomus, sp	....	1	1	4	6
Hyalella, sp	....	2	2	1	....
Crayfish, sp	11	....	1	2	....
Odonata:					
Damselfly nymphs, unidentified	11	15	1	2	2
Ischnura verticalis nymphs	12	3	2	1	....
Enallagma, sp., nymphs	3	2	5	1	....
Lestes, sp., nymphs	6	2	4	5	....
Libellula luctuosa, nymphs	5	....	....	....	....
Anax junius, nymphs	2	....	....	....	....
Erythemis simplicicollis, nymphs	6	4	1	....	....
Algæ:					
Desmids	....	9	4	2	13
Diatoms	....	....	8	2	....
Sponge spicules, in masses	....	5	....	....	....
Œdogonium, scattered filaments	....	....	6	3	14
Algæ filaments	7	7	32	1	25

GENERAL CHARACTER OF THE DIET.—On the whole there is a remarkable similarity in the diet of the various species. Eleven of the food items appear in all five of the columns and nine more are found in four out of the five. There are only three foods confined to a single species and three others that are restricted to two columns.

Perhaps the most noticeable items are those which begin and end the list. Two species of snails are very common in all the ponds, and upon these every kind of nymph examined had been feeding freely. Not only had more than half of the nymphs partaken of these snails, but in several instances no other food was found in their digestive tract.

With reference to the algæ, it is of course understood that inasmuch as the nymphs catch their prey among the algæ, they would be expected to swallow some of the latter. Hence its presence was not noted unless in sufficient quantity to make it reasonably certain that it had been taken voluntarily. Like the snails, in a few instances it constituted the sole article of diet.

The other popular foods were the mayfly larvæ and the small crustacea, the latter being consumed in large quantities.

Cannibalistic tendencies are shown by the presence of odonate nymphs in all five columns; and in four out of the five, nymphs were found which had eaten others of their own species.

There is a good showing of beetle larvæ and adults, and of adult water boatmen, all of which are injurious to young fishes.

SPECIFIC DIFFERENCES IN THE DIET.—Notwithstanding the wonderful agreement just mentioned, a careful examination reveals also striking differences in diet. Every one of the Anax nymphs was fully grown, with well-developed wing cases, and was captured in pond 4, which contained only adult buffalofish. Of course the nymphs could not eat these fish, and hence the absence of fish in their diet is a matter of necessity rather than choice. (See p. 206.) Neither did the fish eat the nymphs, however, and this probably accounts for the exceptional abundance of the latter, as evidenced by the exuviæ obtained. The bulk of the food of these nymphs was made up of mayfly larvæ and snails, but it is worthy of note that they also ate large quantities of Dytiscus larvæ, the water boatman Corixa, and small crayfish. The proportion of odonate nymphs in their food was much greater than for any of the other species examined. One very large specimen had eaten nothing but crayfish, and its stomach was packed full of their shells and claws, which had turned red in color like a boiled lobster. The Dytiscus larvæ were identified by their heads and mandibles, Corixa by the peculiar color pattern of the elytra, and the Haliplid beetles also by the color pattern of the elytra. All three of these foods were especially abundant in this pond.

The bulk of the food of the Libellula nymphs consisted of snails and various entomostraca, Cypris being a particularly toothsome tidbit; there were also quite a number of damselfly nymphs and a good representation of the beetle larvæ. A beetle larva belonging to the genus Peltodyes was found to be common on the algæ in the ponds, and its body was covered with long, jointed, bristlelike processes. The broken fragments of these processes were found in the gizzards of seven nymphs, in three of which the larvæ were the only food eaten.

In the gizzards of five of the nymphs were rounded masses of the spicules of a fresh-water sponge. Sponges are common in two of the ponds, and on them live a species of Sigara, which is a minute water boatman, and one of the caddisworms, Leptocerus.

Of course, the snails crawl about over these sponges, as well as over the algæ. The nymphs probably took in the spicules while feeding on these insects and snails, for they would hardly eat the sponge itself. The Libellula nymphs had eaten a much smaller number of mayfly larvæ than those of Anax and were content with the Amphipod Hyalella, in place of crayfish.

Twenty of these nymphs were taken from pond 7 D, June 23, 1916, while the others came from ponds 1, 2, and 3 D, at different dates in July and August. Pond 7 had been stocked in the spring with 75,000 small fry of the buffalofish; on July 1 these young fish had reached a length of 1 inch, and on July 15 specimens were taken an inch and a half long. Previous to June 23, on this basis of growth, the fish were small enough to be caught and eaten by the nymphs, if the latter had made the attempt. The entire absence of fish from the diet of these nymphs shows that they chose other food even when fish were present. The remains of odonate nymphs in so many of their gizzards is good evidence, on the other hand, that the *luctuosa* nymph is not inert and lethargic.

The food of the Erythemis nymphs consists also of snails and entomostraca, with a moderate amount of beetle and mayfly larvæ, and an almost complete absence of the larger crustacea and of damselfly nymphs. A large amount of algæ was present in 64 per cent of the gizzards, and in several individuals nothing else had been eaten; at least, there were no remains in either gizzard or intestines. Algæ, therefore, must constitute a respectable portion of the food of these nymphs.

It might seem strange to report Simulid larvæ from a fishpond, but the screens at the outlets of all of the ponds were covered with the larvæ of *Simulium vittatum*, and some of the nymphs evidently picked them off the screens. The ephippium surrounding the Cladoceran egg is proof against the digestive juices of the nymphs, and eggs taken from the posterior end of the intestines were as plump and uninjured as those just swallowed. The Desmids and Diatoms, like those found in *luctuosa* nymphs, are not numerous enough to make it certain that they were really sought for and eaten. They might well have been taken in accidentally with some of the food. Ten of these nymphs were taken from pond 7 D on June 26, 1916, and 15 were taken from pond 9 D on July 7. As already stated, the former pond contained an abundance of small fish, while the channel cats in the latter pond had produced a brood of fry previous to the capture of the nymphs. None of them had eaten fish, however, and their small size makes it improbable that they could overpower any but the smallest fry.

Entomostraca and copepods are the chief articles of diet for the Pachydiplax nymphs, and there is a minimum amount of snails, beetle larvæ, and mayfly larvæ. The larger crustacea are practically absent, and damselfly nymphs are the only odonates represented. The food in the gizzards of these nymphs and that in the Erythemis nymphs was particularly well ground up, so that only small fragments were left. Even the shells of the small entomostraca were broken and resembled the débris obtained from the posterior intestine of Anax and Libellula.

The damselfly nymphs included species of Enallagma, Ischnura, Argia, and Lestes, and were obtained from the various ponds indiscriminately. No attempt was made to separate the different species, and they were treated as though all one kind. The food in the gizzards of these numphs was broken up into smaller fragments than that of any of the dragonflies, and in much of it the identification of species or even genera was almost impossible. As will be seen the great bulk of the food consisted of entomostraca of various kinds, with a good percentage of snails. Many of these nymphs also, like those of Erythemis, had eaten large quantities of algæ, and two of the larger nymphs, *Argia mœsta putrida*, had shown cannibalistic tendencies and had eaten smaller nymphs.

BENEFITS OF DIET TO FISH BREEDING.—A very respectable portion of the nymph food consists of the adults and larvæ of insects and crustacea that are known to be injurious to fish fry. Here belong the larvæ of the diving beetle Dytiscus, the adult water boatman Corixa, and the crayfish. The Dytiscus larvæ are known by all fish-culturists to prey upon small fish, and they have been repeatedly observed doing this in these ponds at Fairport, whenever the water is drawn out of them for any purpose. Corixa and the closely related genus Notonecta have proved to be serious pests in European fishponds, killing so many of the young fry that they have to be exterminated before the culture can go on successfully (Benecke, 1886, p. 340).

Crayfish not only prey upon young fish but are also a great nuisance in a fishpond because of their burrowing habits, and therefore anything which diminishes their numbers must be looked upon as beneficial.

Curiously enough the entomostracan genus, Cypris, which is eaten in large numbers by the nymphs of *L. luctuosa* and the various damselflies, is sometimes less innocent than it may appear. In a report on fish-cultural operations at Beaune, France, M. Chabot-Karlen (1889, p. 310), said:

> The rearing of *Daphnia pulex* and *Cypris fusca* was also tried [to serve as fish food]. * * * The Cypris, however, were found to prey upon the young fish. Having been put in with the embryos of the carp, they were often discovered to the number of two or three fixed upon the back of an alevin devouring it, notwithstanding the efforts of the poor animal to shake itself free.

CLAIMS OF INJURIES OF DIET TO FISH BREEDING.—Much of the food eaten by these nymphs is the same as that of small fish, and it is often claimed that they thus diminish the quantity of food available for the fish fry. But the young fish increase rapidly in size, and if they are to be reared successfully larger prey must be provided for them as they grow older. These odonate nymphs furnish such larger prey and are apparently quite acceptable to the fish. (See p. 225.)

Hence if the above argument against the nymphs is to prevail, it must be proved that their value as food for the larger fish plus their value as destroyers of certain enemies of the smaller fish does not recompense for the food they themselves consume plus the few fish fry that the largest species may destroy. This leads very naturally to a discussion of the last statement, which is worthy of separate consideration.

NYMPHS AS FISH EATERS.—There seems to be a prevailing opinion among fish-culturists that dragonfly nymphs are very destructive to young fish, but when we examine the testimony upon which this opinion is founded it does not prove to be very satisfactory.

Two insects were sent to Prof. C. V. Riley for identification in October, 1884, as recorded in Insect Life, volume 1, 1888, page 58. They came from W. L. Jones, of Atlanta, Ga., who stated that the larger one, identified as a nymph of *Anax junius*, was sent to him by a gentleman who stated that "it fastens on the carp fish and finally kills it." Accepting all this as true, we must acknowledge that the evidence is rather indirect and roundabout. No details are given; we are told nothing as to how or when or where; and it is not even stated whether the fish was eaten after being killed, or whether more than one fish was destroyed in this manner.

Another so-called proof has been widely copied by both entomologists and fish-culturists and appeared even in the Cambridge Natural History (Insects, 1901, pt. 1, p. 425). It was originally published in the Hungarian Rovartani Lapok for December, 1884, and consisted of a statement by L. Birò that in a pond belonging to the piscicultural establishment of M. le Comte Palffy at Szomolony, Hungary, only 54 small fish could be found in September, although 50,000 had been placed there the previous spring, but there were present an enormous number of Libellulid larvæ, species not determined. Hence the nymphs must have eaten the fish. The simple facts, however, that the fish were gone and the nymphs were present could hardly be accepted as scientific proof that the latter ate all of the former or any part of them. There are too many other causes which might have removed the fish. It was not even determined to what species the nymphs belonged, none of them were seen eating fish, and no stomachs were examined for fish remains. Then, too, the nymphs found in September, if they were Libellulids, were hatched from eggs laid during that summer and could not have been large enough to eat any fish.

James G. Needham has two records of nymphs eating fish: In Aquatic Insects in the Adirondacks (Needham and Betten, 1901, p. 474) he states that "nymphs of the species described below as *Cordulegaster maculatus* supposition" captured and ate young trout as long as themselves at Saranac Inn, when the trout were placed in their cage. In Aquatic Insects in New York State (1903, pt. 2, p. 213) he says that the nymphs of *Æschna constricta* eat a few trout fry, but he does not tell how this was proved unless his statement on page 212, "I demonstrated this at Saranac Inn by confining them together in a breeding cage" is understood to apply to Æschna as well as to Cordulegaster. That is no proof, however, that trout constitute any part of the regular diet of either nymph mentioned, or of any other nymph.

Warren (1915) found that the nymphs of *Pantala flavescens* would eat practically anything he gave them, even earth worms and chicken lice, but one would hardly care to draw any argument from this fact. When confined together in a besieged fortress or town human beings have been known to eat horses, dogs, or even one another. A nymph must be observed actually eating fish under natural conditions, or fish remains must be found in its stomach when captured, before anything can be really "demonstrated" with reference to its normal diet.

For this reason such pictures as figure 232 on page 389 of The Life of Inland Waters, by Needham and Lloyd (1916), are likely to be very misleading. The authors were there discussing the forage problem in connection with fish culture, and introduced this picture of the nymph of *Anax junius* devouring a small sunfish without a word of comment or explanation. It is evidently a photograph and must have been taken under either natural or artificial conditions. If the conditions were natural, we have a perfect right to know it, because it would add greatly to the value of the picture; but if the conditions were artificial, the picture never should have been published. In either event it is misleading unless fully explained, because it gives the prospective fish breeder the idea that all dragonfly nymphs eat small fish whenever they get a chance. The ordinary individual will comprehend the words "nymph" and "dragonfly," but the specific name, *Anax junius*, will mean nothing to him. He will keep the picture and its implied testimony constantly in mind during his subsequent fish breeding, and it will require long-continued and patient efforts to correct its influence. It is unfortunate that this was not recognized by the authors of a book so admirably designed and executed in its general features.

All the ponds of series D usually contain both Anax and Æschna nymphs, and several of them contain young fishes. When the ponds are drawn, as is done for each of them twice a year and sometimes oftener, the young fish and the nymphs, as well as all the other denizens of the pond, are brought into close contact. At such times crayfish, Dytiscus larvæ, and the like have been repeatedly observed catching and eating small fish, but no dragonfly nymph has been thus far seen attacking a fish. There is always an abundance of other food for them, and they evidently prefer it. In further proof of this 18 Anax and Æschna nymphs were taken from ponds 7 and 9 on July 6, 1916, when they had attained their maximum size. Both ponds at that time contained an abundance of small fish, but no fish remains could be found in the alimentary canal of the nymphs.

Hence when an Anax or Æschna nymph does prey upon fish it may well be because of a scarcity of other food. In evidence of this, Warren (1915, p. 35) has recorded a very interesting experiment. He placed 69 nymphs of *Pantala flavescens* and one of *Anax junius* in a small aquarium and gave them no food except one young fish. At the end of a week there were left 7 Pantala nymphs, the Anax nymph, and the little fish. As long as other food was present, therefore, the fish remained untouched.

Furthermore, Warren examined the contents of the alimentary canal of 253 Anax and Pantala nymphs and found fish in only one of them. (See p. 207.) Even there the remains were so doubtful that he placed a question mark after his identification of them. In a series of experiments made "with the view of finding out how far the food range of the nymphs extended among the aquatic forms of life," he placed various aquatic animals in the breeding jars and allowed the nymphs to eat them at their leisure. Among the forms thus eaten were several kinds of fish, which were common in the localities from whence the nymphs were obtained. Under natural conditions when other food was abundant the fish were not touched, but when brought into the laboratory and deprived of other food the nymphs ate the fish freely.

Garman (1917, p. 441) gave as one of the foods known to be eaten by damselfly nymphs very young fish. No authority was given for this statement, and inquiry has revealed that it was a mistake. We thus see that practically all the positive evidence shows that when an Anax or Æschna nymph does eat a young fish it is because of a scarcity of other food. Even if they do eat them occasionally they also eat enough Dytiscus larvæ, adult Corixas, Cypris, and crayfish to more than offset this. We must remember that it is only with reference to a very few of the largest species that any claims are made—2 dragonflies out of the 27 on the present list. The other 25 and all of the damselflies are admitted to be perfectly harmless so far as young fish are concerned.

AMOUNT OF FOOD CONSUMED.—The nymphs are not only predatory and omnivorous, but they may fairly be called voracious. They gorge themselves to the full extent of their capacity, and the distended gizzard with its dark contents is often visible through the skin and always stands out prominently when the thorax is opened. Usually also the intestine behind the gizzard is filled out into a plump cylinder for 4 or 5 mm. with finely ground indigestible material, such as the mandibles of insect larvæ, fragments of snail shells, broken elytra, etc.

There is a great difference in the amount of food consumed according to the condition of the nymph. Just after a molt the nymph is light in color, yellowish or greenish, and shows a characteristic color pattern very distinctly. As development progresses toward the next molt the color pattern gradually disappears, and the nymph becomes darker and darker until, in *L. luctuosa* and *E. simplicicollis*, it turns to a uniform dark brown.

The nymph eats voraciously as long as it remains light colored; while the color pattern is disappearing the amount eaten also diminishes, and after it has turned brown the nymph's gizzard contains little if any food. All the nymphs whose gizzards were empty were dark-colored, but the intestine usually contained indigestible débris from food previously eaten. One very dark nymph of *L. luctuosa* contained only a single tiny *Cypris inequivala*, another had but one Ceratopogon larva, while a third yielded two Ischnura nymphs with nothing in the intestine. Similarly two dark-colored nymphs of Anax had each eaten but one Ischnura nymph, and the intestines were empty. A dark nymph of *E. simplicicollis* contained only half a dozen short algal filaments with nothing in the intestine. This condition is particularly true of nymphs as they approach their final transformation, when they apparently fast for quite a long period before crawling out of the water. Hence we conclude that an empty digestive tube is one of the essential prerequisites for the great change which then takes place.

Warren (1915, p. 8) has given the lengths of the various instars, meaning by that the periods between molts, during the entire nymphal life of four specimens of *Pantala flavescens*. These periods are about the same length for the first 9 or 10 molts and then increase greatly the last two molts. The final period, corresponding to the pupal stage in insects which have a complete metamorphosis, lasted for a month, while the first nine molts were only five or six days each. He did not record the periods of fasting, but it is probable that these nymphs ate very little during the last week before transformation.

Balfour-Brown (1909, p. 270) similarly found that the periods between molts tend to lengthen as the nymph grows larger. In some of his damselflies there were nearly two months in the last period; in such cases the fast preceding transformation would also be lengthened.

Besides these fasts which accompany the various molts and the one which precedes the final emergence, the nymph is able to go without food for long intervals when necessary and apparently suffer no injury. It is doubtful, however, if a nymph could transform when the fast preceding emergence was considerably lengthened. It is quite possible that some of the failures to fully emerge from the nymph skin (p. 222) may be caused by an insufficiency of food.

FOOD OF HAWAIIAN NYMPHS.—Warren examined the contents of the alimentary canal of 253 Anax and Pantala nymphs captured in the vicinity of Honolulu, Hawaii, and it is interesting to compare his results with those recorded for Fairport. (See table, p. 201.)

FOOD FOUND IN ALIMENTARY CANAL OF 253 ODONATE NYMPHS FROM HONOLULU, HAWAII, EXAMINED BY A. WARREN.

Mollusca: Spiral shells	14
Beetles: Dytiscidæ	16
Flies:	
Chironomid larvæ	168
Chironomid adults	4
Mosquito larvæ and pupæ	12
Mosquito adult	1
Dolichopodid fly	1
Adult fly, undetermined	1
Bugs:	
Merragata hebroides (Næogeidæ)	1
Microvelia vagans (Veliidæ)	2
Ants and bees:	
Pheidole megacephala (Myrmicidæ)	2
Ants, undetermined species	11
Dragonflies: Pantala flavescens, nymphs	6
Crustacea:	
Cypris, sp	108
Shrimps, sp	3
Protozoa: Euglena, sp	30
Worms: Nereis, sp	1
Amphibians: Tadpoles	8
Fish: Top minnow (?)	1

The first thing to be noticed is the general similarity in the food. The Hawaiian nymphs ate mollusks, beetles, flies, bugs, crustacea, odonates, and protozoa, the same as the Fairport nymphs. Many of the food species were different, as would naturally be expected, but they belong to the same families and sometimes to the same genera. Unlike the nymphs at Fairport, those at Honolulu ate bees, ants, and adult Chironomids, mosquitoes, and flies. These land insects undoubtedly dropped into the water before they were captured, and Warren has suggested that since the Hawaiian streams and pools contain but few aquatic insects, while the dragonfly nymphs are numerous in many localities, the latter must obtain a part of their food from land insects that fall into the water. This idea induced him to try them with all kinds of land insects, and he found they would eat anything he offered. (See p. 206.)

Tadpoles also appear in their diet, probably due to the scarcity of insect food just mentioned and also to the fact that the frogs and dragonflies are compelled to breed in restricted bodies of water, so that they are brought into close contact. Another result of the scarcity of insect food is that the majority of the nymphs fed upon a single Chironomid species, *Chironomus hawaiiensis*, and upon the crustacean genus Cypris. If the food had been more plentiful there would have been a greater variety in the diet. Consequently the extreme variety in the food of the Fairport nymphs is a good indication of the richness of the food supply.

FOOD OF NYMPHS FROM ITHICA, N. Y.—A table has been made out by Miss Lyon (1915) showing the food of 36 nymphs, distributed among 3 Æschnid species, 2 Gomphids, 4 Libellulids, and 4 damselflies. Cascadilla Creek, from which the nymphs were obtained, flows along the southern border of the Cornell University campus at Ithaca. The nymphs were collected at intervals from November to July, thus covering nine months of the year.

For the sake of convenience, her figures have been reduced to the same method of treatment as used in the statement on page 201.

FOOD FOUND IN ALIMENTARY CANAL OF 36 ODONATE NYMPHS FROM CASCADILLA CREEK, ITHACA, N. Y., EXAMINED BY M. B. LYON.

Mollusca: Physa, partly digested	1
Beetles: Dytiscus, sp	2
Diptera:	
Chironomid larvæ	24
Mosquito larvæ, Anopheles, sp	1
Undetermined larva	1
Hemiptera:	
Corixa nymphs	6
Corixa adults	2
Ephemeridæ:	
Heptagenia, sp	4
Hexagenia, sp	1
Cænis, sp	1
Undetermined mayflies	2
Crustacea:	
Hayalella, sp	5
Diaptomus, sp	2
Crustacea—Continued.	
Cyclops, sp	2
Cypris, sp	2
Undetermined	1
Odonata:	
Libellulid, sp., nymph	1
Ophiogomphus, sp., nymph	1
Damselfly nymphs	9
Arachnid:	
Mite	2
Macrobiotus, sp	1
Algæ:	
Diatoms	5
Closterium, sp	3
Œdogonium, sp	1

Miss Lyon's investigations showed that while Chironomids, mayflies, and odonates were eaten voraciously throughout the year, the crustacea and Hemiptera were confined to the warmer months, when they are present in greater numbers. The abundance of crustacea in the Fairport list will thus depend somewhat upon the fact that all the nymphs were examined during the months of July and August.

Conclusions.—Comparing the three food lists here presented from widely separated localities, it would seem that odonate nymphs eat very much the same food everywhere. They feed largely upon insects and are able to confine themselves practically to a single species that happens to be abundant, as in Hawaii, or they may extend their diet to include a rich variety of genera and species, as in the other two lists. In her text notes Miss Lyon enumerates 11 species that could be identified amongst the Chironomid larvæ, with the probability that still others were represented in the unidentified material.

Judging from the lists, odonate nymphs do not devour many mosquito larvæ or pupæ, although Warren (1915) was firmly convinced that the Hawaiian nymph was a great destroyer of mosquitoes, in spite of the unfavorable showing of his list. He even fed some of his nymphs with mosquito larvæ and adults. One Pantala nymph ate during a single night 40 imagos of *Stegomyia scutellaris* that had been stunned with cyanide fumes and placed in the aquarium with the nymph. Another Pantala nymph ate 75 full-grown mosquito larvæ within 12 hours. But here, as in the eating of the fish, no convincing argument can be drawn from what is fed to a nymph when no other food is available.

The food of the odonate nymphs is by no means confined to insects, however; they also eat quantities of crustacea and mollusks and may include protozoa, algæ, and even vertebrates in their diet. In fact, the nymph seems capable of accommodating itself wonderfully well to its environment and can seemingly thrive upon whatever form of food happens to be available. Consequently if the nymphs are introduced into a fishpond, no special food will need to be provided for them. If the pond is stocked with the usual insect larvæ, crustacea, etc., whatever the species may be, the nymphs will quickly adapt themselves to them.

ENEMIES OF ODONATE NYMPHS.

1. Fish.—A full discussion of nymphs as food for fishes is given on page 225.

2. Larger Nymphs.—The proportion in which the smaller nymphs are destroyed by the larger ones is well shown in the table and statements already given.

About 20 per cent of the food of Anax nymphs and 10 per cent of the food of the nymphs of *L. luctuosa* consist of other nymphs smaller than themselves. In general, the nymphs that are eaten belong to a different genus, but the large nymphs are cannibalistic as well as rapacious and sometimes eat others of their own species. This is not as likely to occur, because all the nymphs of a given species develop at about the same time and are consequently nearer the same size. But they always vary more or less in their rapidity of growth, so that some are larger than others, and even if two were of the same size it would not be safe to keep them together unless plenty of suitable food were provided for them. If they once became real hungry, they would fight it out and the stronger would devour the weaker. To protect themselves against one another, as well as against all their enemies, the Gomphid nymphs habitually burrow in the mud or débris of the bottom; *L. luctuosa* and the heavier Libellulids sprawl amongst the rubbish, while Erythemis, Celithemis, Tramea, etc., and all the damselfly nymphs hide in the matted vegetation. Such lurking places also serve as admirable ambushes whence to secure their prey.

3. Diving Beetles, Water Scorpions, and Aquatic Hemiptera.—These retaliate by eating the nymphs before they are large enough to defend themselves. An adult Dytiscus beetle was seen in pond 7 eating a small Erythemis nymph, which would partly compensate for the beetle larvæ of the same species that are found in the table on page 201. Dr. Muttkowski has observed both Dytiscus and Zaitha feeding upon nymphs and noted that after capturing the nymph they invariably stick their beak first into its head. Garman (1917, p. 441) has recorded that "among aquatic Hemiptera the genera Ranatra, Belostoma, and Notonecta, and probably others feed upon damselfly nymphs." The fact that the water boatman, Notonecta, attacks the nymphs of dragonflies was also recorded by W. J. Lucas (1908, p. 16).

4. Fresh-water Hydra.—Another enemy of the nymph is found in the common hydra; the green species, *H. viridis*, does not probably reach a size sufficiently large to overcome even a newly hatched nymph, but the brown species, *H. fusca*, can and does eat small nymphs. Two leaves of *Potamogeton illinoiensis*, which contained a large number of Enallagma eggs that were just hatching, were brought into the laboratory August 11, 1917, and placed in a small aquarium. On going over them with a hand lens to remove the nymphs already hatched, a large brown hydra was found eating one of the tiny nymphs. It was attached to the under surface of the leaf, nearly in the center of a large cluster of the Enallagma eggs, and could reach many of the nymphs with its tentacles as they emerged. If this species of hydra became at all plentiful in a fishpond it might kill a large number of the young nymphs.

5. Nematodes.—Good-sized specimens were found in the stomachs of several nymphs of both Anax and *L. luctuosa*, and Needham (1898, p. 86) found the intestine of a nymph parasitized by large Gregarines a millimeter in length. An Enallagma nymph examined July 27, 1917, contained a dozen large Gregarines, and several others contained one or two apiece. These intestinal parasites probably never become numerous enough to actually kill their host, but their presence may weaken the nymph and make it more susceptible to its other enemies.

6. Parasitic Mites and Flies.—Some of the Ischnura and Enallagma nymphs were found infested with small mites between the wing pads and around the bases of the legs; 10 of these were taken from a single Ischnura nymph.

Mrs. Aaron (Lamborn, 1890, p. 50) mentioned another small red mite "which skims rapidly over the water in search of an Odonat egg, upon which it either deposits an egg or excavates it for immediate nourishment." She also saw one of the parasitic Diptera ovipositing on the egg of Diplax. In these two cases, of course, the larvæ of the mite and the fly when they hatch feed upon the dragonfly's egg.

Needham (1903) reported that many hymenopterous parasites prey upon the eggs of Lestes, which are inserted in plant tissues above the water line, where they are exposed to such attacks. He succeeded in rearing three species of the parasite, belonging to different genera.

Brandt (1869) similarly reported rearing another parasite, *Polynema ovulorum*, from the eggs of Agrion (Calopteryx), and added that half the eggs were sometimes destroyed in this way.

7. Algæ, Fungi, and Vorticellids.—"The Confervoid alga, Œdogonium, is often found growing upon the larva of *Æschna brevistyla.* I found by means of sections that the Œdogonium does not penetrate the cuticle of the larva, but simply grows on it as it grows on everything else in such places. On one larva of Æschna there were no less than 3 species of Œdogonium, 15 species of Diatoms, and a large number of Vorticella." (Tillyard, 1917, p. 332.) Œdogonium is very common in several of the ponds at Fairport and is found growing over many of the pond contents, including nymphs, but it appears to do them no injury further than to impede their movements slightly.

Miss Lyon (1915, p. 5) published a table giving the Diatoms, green and blue-green algæ, the protozoa, and the epizoa found growing upon the nymphs of Cascadilla Creek She noted the similarity between these species and those of the mud and water plants in the immediate vicinity. She concluded that the relationship between the two was simply a natural one, resulting from the proximity of the various forms, and not one of symbiosis, as Kammerer and others would have us believe.

Similarly a Saprolegnious fungus frequently attacks damselfly nymphs, especially if they are enfeebled from any cause. This fungus is related to the one attacking young fishes and often causes the death of the nymph. (Garman, 1917, p. 442.)

8. Birds.—Needham has recorded dragonfly nymphs as found in considerable numbers in the stomachs of herons (1898, p. 85). McAtee (1912) also recorded nymphs as forming part of the food of the horned grebe, *Colymbus auritus.* But herons and grebes and their kin are deadly enemies of fish, and hence should always be kept away from fishponds. Under natural conditions, however, they might well consume a considerable quantity of nymphs.

9. Reptiles.—Martin (1886, p. 232) said with reference to the Odonata of the Département de l'Indre in France:

> The eggs, larvæ, and nymphs are the prey of several fishes, snakes, newts, Coleoptera, aquatic Hemiptera, and of some diving birds. Sometimes the destruction is on a considerable scale, and one may notice the dragonflies of some piece of water diminish gradually in numbers, while the animals that prey on them increase, so that a species may for a time entirely disappear in a particular spot, owing to the attacks of some enemy that has been specially prosperous and also eager in their pursuit.

Baker (1906, pp. 231, 232) in his study of The Relation of Mollusks to Fish in Oneida Lake found numerous dragonfly nymphs in the stomachs of painted terrapins, *Chrysemys picta.*

None of the terrapin at Fairport were examined for the food they had eaten, but they may fairly be reckoned among the enemies of the nymphs.

Ordinarily the dragonfly nymph is able to hold its own in spite of its enemies, and it requires conditions exceptionally adverse to the nymph and exceptionally favorable to its foes before there is any danger of the extermination of the nymphs.

FOOD OF ODONATE IMAGOS.

There are several things which make it difficult to obtain specific lists of the food of the imagos similar to those presented for the nymphs.

A considerable portion of the animals eaten by the nymphs, such as snails, entomostraca, beetles, hemiptera, and the like, are inclosed in hard shells or elytra, which persist inside the digestive canal of the nymph and are easily recognized. The food of the imagos, however, consists chiefly of soft-bodied insects, destitute of elytra, or of insects from which the harder parts, if present, are carefully rejected. Consequently the only things that can be recognized with any certainty in the contents of the imago's digestive canal are an occasional mandible or maxilla, portions of the wings of various insects, legs and antennæ, scales of butterflies and moths, hairs, and claws. The accurate identification of such minutiæ is a painstaking and laborious task, and the frequency with which the species or even the genus must be left undetermined is not surprising.

Again, the nymph swallows much of its food whole or at least in large fragments, so that the relation of the various parts remains undisturbed. The imago, on the other hand, believes in thoroughly masticating its food, and every mouthful is chewed into fine fragments before being swallowed. At the same time such parts as the wings and legs, which would be of great value for identification, and even the harder tissues of the body, are carefully rejected. Occasionally fragments of a wing or elytron are sometimes included, but they are usually badly torn and often lack the very part that is wanted. The imago is particularly fond of teneral insects, whose chitin has not yet hardened, and whose pigment markings have not been developed. Such insects, after being chewed and swallowed, form an indistinguishable mass in which there is very little hope of finding anything that can be identified.

A third difficulty is found in the fact that, although the digestion of the nymph's food is comparatively slow and the large fragments are recognizable for some time after they have been swallowed, the food of the imago, on the other hand, is digested with exceptional rapidity and must be examined as soon as it is swallowed, if anything definite is to be hoped for. Even the short space of time between the insertion of the insect into a cyanide bottle and its subsequent death is sufficient to materially affect the contents of the alimentary canal, and the changes apparently continue a short time after the insect's death. To obviate this, good results were obtained by making an incision in the thorax and abdomen, and then plunging the imago into 95 per cent alcohol as soon as it was taken from the net. All the examinations of the alimentary canal here tabulated were made in this way.

In view of these difficulties the most feasible method of determining the food of the imago is to watch it while feeding and capture it with enough of its food still uneaten to render identification possible. That this method has proved very satisfactory is shown by the frequency with which it appears in the following statements. In addition, all the available American records have been included, with acknowledgment of their source.

FOOD OF GOMPHID IMAGOS, FAIRPORT, IOWA, 1916.

Gomphus fraternus:	
Diptera—House fly, *Musca domestica*	Captured while eating.
Trichoptera—Caddisfly, undetermined	In alimentary canal.
Odonata—	
Erythemis simplicicollis	Needham and Hart, 1901, p. 64.
Libellula luctuosa	Captured while eating.
Argia mœsta putrida	Do.
Teneral dragonflies	In alimentary canal.

Food of Gomphid Imagos, Fairport, Iowa, 1916—Continued.

Gomphus vastus:	
Diptera—House fly, *Musca domestica*	Seen picking from window screen.
Trichoptera—	
Caddisfly, undetermined	In alimentary canal.
Caddisfly, *Macronema zebratum*	Walsh, 1862, p. 391.
Ephemeridæ—Mayfly, *Hexagenia*, sp	Captured while eating.
Odonata—	
Libellula luctuosa	Do.
Leucorrhinia intacta	Do.
Argia mæsta putrida	Do.
Libellulidæ	Needham and Hart, 1901, p. 21.
Dragonfly tenerals	In alimentary canal.
Dromogomphus spoliatus:	
Lepidoptera—*Pieris rapæ*	Williamson, 1901, p. 119.
Odonata—	
Hetærina americana	Do.
Argia mæsta putrida	Do.

Food of Æschnid Imagos, Fairport, Iowa, 1916.

Anax junius:	
Diptera—	
Mosquito, *Culex*, sp	Taken from mouth.
Black fly. *Simulium*, sp	In alimentary canal.
Midge, *Chrironomus*, sp	Captured while eating.
Midge, *Ceratopogon*, sp	In alimentary canal.
Syrphid fly	Captured while eating.
Undetermined flies	In alimentary canal.
Ephemeridæ—	
Mayfly, *Calliabetes*, sp	Captured while eating.
Mayfly, *Hexagenia*, sp	Do.
Trichoptera—Caddisfly, undetermined	In alimentary canal.
Lepidoptera—	
Butterfly, undetermined	Scales in alimentary canal.
Moth, Tortricidae	Captured while eating.
Butterfly, *Ancyloxypha*, sp	Do.
Odonata—	
Leucorrhinia intacta ♂	Do.
Erythemis simplicicollis ♀	Do.
Argia mæsta putrida ♂	Do.
Damselflies, undetermined	In alimentary canal.
Æschna constricta:	
Diptera—	
House fly, *Musca domestica*	Seen picking off screen door.
Mosquito, *Culex*, sp	Taken from mouth.
Æschna brevistyla:	
Diptera—	
Mosquitoes	Tillyard, 1917, p. 328.
Gnats	Do.

Food of Libellulid Imagos, Fairport, Iowa, 1916.

Leucorrhinia intacta:	
Diptera—	
House fly, *Musca domestica*	Seen picking off window screen.
Midge, *Chironomus*, sp	In alimentary canal.
Muscid fly, *Sarcophaga*, sp	Captured while eating.

Food of Libellulid Imagos, Fairport, Iowa, 1916—Continued.

Leucorrhinia intacta—Continued.	
Lepidoptera—	
Butterfly, undetermined	Scales in alimentary canal.
Butterfly, *Lycaena comyntas*	Captured while eating.
Ephemeridæ—Mayfly, *Calliabetes*, sp	Do.
Odonata—	
Enallagma civile ♂	Do.
Enallagma hageni ♂	Do.
Tenerals, undetermined	In alimentary canal.
Libellula luctuosa:	
Diptera—	
House fly, *Musca domestica*	Taken from mouth.
Muscid fly	In alimentary canal.
Midge, *Chironomus*, sp	Do.
Lepidoptera—	
Lycæna comyntas	Captured while eating.
Butterfly, undetermined	Scales in alimentary canal.
Moth, Tortricidæ	Captured while eating.
Odonata—	
Ischnura verticalis	Do.
Leucorrhinia intacta	Seen eating.
Sympetrum, sp	In alimentary canal.
Tenerals, undetermined	Do.
Ephemeridæ—Mayfly, undetermined	Do.
Erythemis simplicicollis:	
Diptera:	
House fly, *Musca domestica*	Seen picking off window screen.
Midge, *Chironomus*, sp	In alimentary canal.
Sarcophaga sarracenia	Captured while eating.
Tabanid fly, *Chrysops*	Williamson, 1900, p. 326.
Lepidoptera—	
Hæmatopsis gratavia	Captured while eating.
Ancyloxcypha numitor	Do.
Pamphila, sp	Williamson, 1900, p. 326.
Pieris rapæ	Captured while eating.
Ephemeridæ—Mayfly, undetermined	In alimentary canal.
Odonata—	
Erythemis simplicicollis	Captured while eating.
Argia mæsta putrida	Do.
Enallagma hageni	Do.
Lestes vigilax	Williamson, 1900, p. 326.
Argia violacea	Do.
Lestes unguiculatus	Captured while eating.
Plathemis lydia:	
Diptera—House fly, *Musca domestica*	Seen picking off window screen.
Lepidoptera—*Ancyloxcypha numitor*	Captured while eating.
Celithemis eponina:	
Diptera—Syrphid flies	Do.

Food of Damselfly Imagos, Fairport, Iowa, 1916.

Enallagma hageni:	
Diptera—	
Midge, *Orthocladius*, sp	Captured while eating.
Midge, *Corynoneura*, sp	Do.
Midge, *Chironomus*, sp	In alimentary canal.

FOOD OF DAMSELFLY IMAGOS, FAIRPORT, IOWA, 1916—Continued.

Enallagma hageni—Continued.	
Diptera—Contiuued.	
Dolichopodid fly	Captured while eating.
Anthomyiid fly	Do.
Syrphid fly	Do.
Simulium vittatum	Taken from mouth.
Undetermined flies	In alimentary canal.
Palpomya, sp.	Captured while eating.
Nematocera, sp.	Garman, 1917, p. 445.
Lepidoptera—*Ancyloxcypha numitor*	Captured while eating.
Odonata—	
Ischnura verticalis	Do.
Enallagma, sp. (dead)	Seen eating.
Ischnura verticalis:	
Diptera—	
Midge, *Orthocladius*, sp.	Captured while eating.
Grass-stem fly, Geomyzidae	Do.
Midge, *Chironomus*, sp.	Do.
Undetermined	Do.
Lepidoptera—Butterfly	Garman, 1917, p. 445.
Ischnura kellicotti: Diptera—Undetermined	Williamson, 1899, p. 280.
Lestes vigilax: Diptera, Nematocera	Garman, 1917, p. 445.
Argia mœsta putrida:	
Coleoptera—Beetle, *Berosus striatus*	Captured while eating.
Ephemeridæ—	
Mayfly—*Calliabetes*, sp.	Do.
Mayfly—*Hexagenia*, sp.	Do.
Hemiptera—Plant louse, *Aphis*, sp.	Do.
Diptera—Undetermined flies	In alimentary canal.
Argia apicalis: Diptera—Nematocera	Garman, 1917, p. 445.
Enallagma civile and *E. antennatum:* Diptera—Nematocera.	Do.

GENERAL STATEMENT.—Williamson (1899, p. 235) has given one of the best general statements.

> The food of the imagos consists almost entirely of other insects, though some are known to occasionally eat the flesh of dead animals. Of the insects eaten Diptera are more preferred than any other order, though all soft-bodied insects seem to fall a prey to their ravenous appetites. Larger species eat their smaller relations. Leaf hoppers and other Hemiptera and Lepidoptera are consumed.

The above statements very strongly substantiate Williamson's statement that the Diptera form a favorite food. Every odonate species included in them, with one exception, has eaten Diptera of some sort. And, curiously enough, all we know about the food of this one exception, *Dromogomphus spoliatus*, is derived from Williamson himself. Some of the species, such as *Anax junius* and *Enallagma hageni*, show a decided preference for flies and midges. The statement that the larger species eat the smaller ones is also well verified, even among the damselflies.

Williamson also recorded on the same page that he once captured a dragonfly holding a large wasp in its mandibles. There were two wasps in Poulton's list of the prey of the Odonata (1906, p. 399), and honeybees were included in Campion's list (1914, p. 499). The English paper Field for March 21, 1908 (p. 486), mentioned a bee keeper in Australia who complained that the dragonfly destroyed more of his bees than any of the birds. None of these records were American, but they serve to indicate that our

American species may possibly eat more Hymenoptera than we are aware. Termites, winged ants, and cicadas are also interesting victims of the odonata which have been recorded in other parts of the world. A dragonfly is reported to have dug a cricket out of the ground and eaten it (Habit of a Dragonfly, editorial notes, Psyche, vol. 5, p. 364), but this is the only instance, so far as known, where odonates have eaten any of the Orthoptera.

SIZE OF PREY.—Perhaps the food of the damselflies is usually made up of smaller insects than that of the dragonflies, but the size of the prey is not always in proportion to the size of the imago that eats it. Æschna and Anax, two of our largest dragonflies, are among the most persistent eaters of gnats, midges, and mosquitoes, while one of the favorite foods of the damselfly, *Argia mœsta putrida*, is a black mayfly almost as large as itself. Like that of the nymphs, the appetite of the imago seems well-nigh insatiable, and no sooner is one insect devoured than another is caught. Stories of the amount eaten by some imago are told by nearly every observer, and the present author would add one more to the list. A male *A. m. putrida* was given eight black mayflies, one after the other, and he ate every one of them, simply throwing away the legs and wings; yet any two of them exceeded in bulk the damselfly's whole body, minus its wings and legs.

SOURCE OF FOOD SUPPLY.—The food is usually captured in greater or less proximity to the water, sometimes being picked off the very surface of the latter. However, the female dragonfly habitually hunts at a greater distance from the water than the male. The females of *Plathemis lydia* and *Perithemis domitia* are only rarely seen around the ponds. The females of other species come to the water for the purpose only of laying their eggs, while the males are constantly patrolling the surface of the ponds, as well as the banks in the immediate vicinity.

Even the males, however, do not obtain all their food near the water. Anax, Æschna, *Libellula pulchella*, Tramea, and Epicordulia make long foraging trips out into the surrounding country and are often found a considerable distance from any body of water. In this way they help to rid the countryside of some of its worst insect pests, especially flies, mosquitoes, gnats, and midges. Such foraging trips are made more often late in the afternoon, toward sunset, and sometimes after. The males, and occasionally a female, of many of the species around the ponds came regularly every evening to the laboratory building and hawked for food. They picked flies off the window screens and the sides of the building, they decimated the hordes of gnats and midges that swarmed in the waning sunshine, and sometimes they ascended high in the air in search of the tiny insects to be found there. Occasionally their hunting was prolonged after sunset, when the insects were particularly numerous. *Libellula luctuosa* was the most common of these visitors, but they also included Erythemis, Leucorrhinia, Plathemis, Tramea, Pantala, Anax, Æschna, and even *Gomphus vastus* and *G. fraternus*.

MIGRATION OF TENERALS.—As soon as possible after emerging the teneral imagos of *Libellula luctuosa* fly back onto the prairie, away from the ponds and the river. There they remain in the gullies and among the underbrush until they become ready for pairing and egg laying. A trip of a mile or two up some of the gullies leading back onto the prairie will reveal thousands of these tenerals roosting on the weeds and underbrush. Occasionally an imago of Erythemis, Leucorrhinia, some Gomphus species, or an Enallagma will be found with them. Usually there is no water within reach, but if there happens to be a small brook at the bottom of the gully fully developed imagos of *Libellula pulchella* and Plathemis will be found, as is usual in such places. These hordes of tenerals are simply resting and feeding in comparative security until they become ready for the active duties of propagation. The time thus occupied is apparently about five or six days but is difficult to determine, because new tenerals are arriving and matured individuals are leaving all the time, and it is practically impossible to tell just how long any of them remain.

It is probably a similar retirement from the vicinity of the water during the interval between emergence and sexual activity that accounts for the disappearance of some of the Gomphus species. (See p. 188.)

The food obtained in these gullies and out on the prairie is of necessity somewhat different from that captured around the ponds, but still consists largely of flies, gnats, and mosquitoes, with an occasional lepidopter.

PERIODIC EATING.—Since most of their prey is captured while on the wing, when it is bright and sunny the imagos are eating much of the time, while in dull and cloudy weather they eat very little, if at all.

Microscopic examination of the digestive tract shows that the newly emerged tenerals do not eat anything for a day or two, until about the time their color pattern is fully formed. Probably the tenerals of *L. luctuosa* just mentioned take no food before reaching the gullies and the prairie. Other tenerals that remain near the ponds of course obtain their first food there.

Again, such an examination shows that, while the imago is voracious and often feeds all the time, we can still distinguish two periods of maximum eating, fairly well marked. Whatever is eaten during any day is all digested long before the next morning, so that imagos captured before leaving their roost in the morning will have nothing in their gizzards and very little in the intestine. Accordingly the first period of maximum eating comes in the forenoon, shortly after the imago leaves its roost, as soon as the insects which constitute its food begin to swarm. This is followed by a lull, or at least a diminution in the amount eaten, which lasts until well into the afternoon, and during this period they are occupied with mating and egg laying. The eating then increases again, and the second period of maximum feeding, which is more intensive than the first, comes toward sunset.

Of course, it will be understood that there is no intention of implying that imagos eat two meals a day, or anything of the sort. There are simply more of them feeding in the morning and late in the afternoon and more of them depositing their eggs through the middle of the day. Moreover, the gizzards of those captured at 9 or 10 a. m. and toward sunset are more apt to be well filled. They are thorough believers, however, in eating between meals, and are not restrained in their desires by any irksome rules of hygiene.

FOOD FOUND IN THE ALIMENTARY CANAL OF 218 IMAGOS OF PANTALA FLAVESCENS IN HAWAII.

Diptera:	
Midges, *Chironomus hawaiiensis*	1
Night mosquitoes, *Culex fatigans*	1
Day mosquitoes, *Stegomyia scutellaris*	1
Undetermined mosquitoes	3
Pomace flies, Drosophilidæ	3
Undetermined flies	140

Food Found in the Alimentary Canal of 218 Imagos of Pantala Flavescens in Hawaii—Continued.

Coleoptera:	
Scarabæid beetle, *Psammodius*, sp	22
Bostrichid beetle, *Rhizopertha pusila*	1
Staphylinid beetle	31
Undetermined beetles	30
Hemiptera:	
Plant lice, Aphidæ	24
Water boatman, *Corixa blackburni*	4
Leaf hopper, *Perkinsiella saccharicida*	4
Leaf hopper, *Draeculacephala mollipes*	3
Leaf hopper, *Nesophrosyne perkinsi*	3
Chinch bugs, Lygæidæ	2
Lace bugs, *Teleonemia lantanæ*	4
Undetermined species	1
Hymenoptera:	
Apis, not the Honeybee	1
Parasite, *Chelonus blackburni*	1
Parasite, *Paranogrus optabilis*	1
Undetermined Hymenopterous parasites	3
Myrmicid ants, *Pheidole megacephala*	6
Undetermined ants	11
Lepidoptera:	
Tineid moth, *Cremastobombycia lantanella*	5
Undetermined forms	72
Odonata: Damselfly, *Agrion*, sp	1
Book lice: Psocidæ	8
Thysanoptera: *Thrips*, sp	9
Arachnida:	
Mites	1
Spiders	2

Food of Pantala flavescens in Hawaii.—This statement is inserted here for several reasons. It is by far the most complete statement of the food of a single odonate species that has ever been published. This same species is one of those around the ponds at Fairport, and it is widely distributed throughout the United States. Hence a list of its food in Hawaii will give a good idea of the kind of insects it would be likely to eat elsewhere. It is also instructive to compare the Hawaiian foods with those eaten at Fairport. We notice that flies, beetles, and Lepidoptera make up the bulk of the food of this species in Hawaii. There are also present many kinds of Hemiptera or true bugs, especially plant lice, adult water boatmen, and leaf hoppers, some hymenopterous parasites, ants, and Thrips, a tiny insect which feeds upon the flowers and leaves of some plants.

In the Fairport list there is a much greater variety of both flies and Lepidoptera, but there are no beetles at all, and the only bug is the plant louse. Their place seems to be taken by the mayflies and caddisflies, which are lacking in the Hawaiian list.

Economic Value of these Foods.—The chief concern here is the effect upon the life of the fish produced by such wholesale and untiring destruction of the insects around the ponds, as is revealed in these food lists. In dealing with this problem certain considerations are forced upon the attention.

It will be urged, in the first place, as in the case of the nymphs, that the killing of so many adult Chironomids, Ephemerids, and Culicids seriously diminishes the number of egg layers around the ponds, and thus affects the supply of fish food. Would it not be better to get rid of the dragonflies and allow these other insects to breed without hindrance? At first sight it seems as if the answer must be in the affirmative, but a little reflection makes it appear differently. If the nymphs of the dragonflies make as good food for the larger fish as the larvæ of these other insects make for the smaller fish, then it is as important for the dragonfly imago to survive and lay its eggs as for any of these other species. Larger fish will not thrive well on food suitable for fry, and if something is not provided for them they will eat one another. Bass, perch, sunfish, buffalofish, catfish, and crappies are well satisfied with the larvæ of mosquitoes, gnats, and flies for a while and will thrive on them. But the time soon comes when this food no longer satisfies them and they demand something larger. (See p. 225.)

The period during which the smaller larvæ prove sufficient varies considerably with the kind of fish, but they will all thrive better if the larger food is present in the pond, so that they can change to it gradually whenever they choose. It is definitely shown in another place (p. 228) that when the young fish reaches a length of about 25 mm. it begins to eat odonate nymphs. It takes some fish much longer to reach this length than it does others, and even in the same brood some fish grow faster than others. Hence the larger food must be present all the time to accommodate the different rates of growth.

Furthermore, actual observation shows that the presence of odonate nymphs and imagos does not necessarily diminish the supply of smaller fish food. The number of dragonflies has steadily increased around the Fairport ponds during the last five years, but at the same time the number of other insect larvæ and Entomostraca has increased apparently as much, so that conditions suitable for fish culture were never better than at the present time.

Again, whatever the kinds of fish, they must be successfully carried through the winter, and there must be enough food in the pond to keep them in good condition. By the time the pond freezes over most of the young fish have become large enough to demand good-sized food, and the larger they grow the more insistent will this demand become. Moreover, some of the animals which are included among this smaller food, such as the Entomostraca and several of the insect larvæ, are much less numerous during the winter. At other times of the year odonate nymphs furnish acceptable food for fish, and there is every reason to believe that they continue to do this through the winter, which is just the season when it is most needed. Only a few fish have been examined at Fairport during the winter, but the limited observations that have been made seem to support this idea. Twelve largemouth black bass, *Micropterus salmoides*, averaging 130 mm. in length and 18 bluegills, *Lepomis incisor*, averaging 107 mm. in length, from pond 1D, 19 of the same bass, 44 mm. in length, from pond 2D, and 12 bass, 185 mm. in length, from pond 3D, were examined February 15–17, 1917. Of these 61 fish, the stomachs of 46 were found to be either entirely empty or so near it that the dèbris present was indistinguishable. The food of four of the remaining fish, two bass and two bluegills, consisted entirely of odonate nymphs, and they were probably identified in the dèbris of the stomachs of two other bluegills. This record is too meager to possess much value beside the ample proof elsewhere presented (p. 225), but it does show that the fish will eat nymphs during the winter, as suggested.

As a third consideration, although nature's equilibrium must be made subservient to man's designs and control in intensive pondfish culture, it is still true that, other things being equal, the more natural the pond and its surroundings can be kept the greater will be the likelihood of success. Artificial conditions are usually difficult of maintenance and should be established only when necessary. The dragonflies and nymphs constitute an important factor in the environment of the ordinary fishpond, and even their voracious appetite is accounted for in nature's methods of equalizing things. This is shown by the fact that they eat one another with as much avidity and as little compunction as is shown toward any other kind of food. Their removal, therefore, would considerably disturb the balance and impose artificial conditions that might be difficult to handle. The station is having much success in rearing various kinds of fish, among which are the buffalofish and channel catfish, whose breeding is admitted to be very difficult. Some of this success may well be due to the maintenance of a natural equilibrium in the animal and vegetable life of the fishponds.

Tillyard (1917, p. 335) has suggested that such an equilibrium may be advantageously modified without in the least impairing its value:

> Not only are the dragonflies the most powerful determining factor in preserving the balance of insect life in ponds, rivers, lakes, and their surroundings, but they do most certainly make war upon the flies, mosquitoes, and gnats, which we all desire to see exterminated. I believe that a successful checking of the mosquito pest in the ornamental waters of parks and gardens could be readily obtained by the introduction of species whose larvæ, as well as the imagines, would prey upon the nuisance. If a successful planting of a colony of dragonflies in such a position were to be tried, the species selected might also be chosen for its coloring, and thus add a new note of interest to the locality. The glorious red *Orthetrum villosovittatum* has now become well established in the Botanical Gardens at Brisbane (Australia) and certainly adds a vivid touch of color to its lovely surroundings.

The suggestions herein contained naturally lead up to the next consideration, which seems worthy of a separate heading.

ODONATES AS DESTROYERS OF MOSQUITOES, GNATS, AND FLIES.—The quiet waters of an artificial fishpond furnish admirable conditions for the breeding of mosquitoes, and the screens at their outlets afford similar breeding places for gnats. The mosquitoes may include, in the proper geographical localities, both *Anopheles* and *Stegomyia*, the carriers of malaria and yellow fever. Obviously in a fishpond these pests can not be kept down by treatment with an oil film, neither can they be allowed to breed unhindered. The consumption of the larvæ by young fish might furnish an important check, but in intensive fish culture very little attention can be paid to the attitude of the fish toward mosquito larvæ.

Of the nine ponds in series D at Fairport six were stocked in the spring with fish that would not eat mosquito larvæ. In some of these ponds broods of young fish were raised later in the season, but previous to their appearance the mosquitoes could breed unhindered by the fish. In at least two of the six ponds no young fish were raised, or they were removed before they had time to produce any effect upon insect larvæ. Here, therefore, so far as the fish were concerned, the mosquitoes might hold undisturbed sway during the entire season.

No fish eats adult mosquitoes; when the pupæ are once safely transformed into imagos they are in no danger of further molestation from that source. Hence if the fishpond is to be prevented from serving as a breeding ground for these obnoxious pests some other check must be provided. Mention has already been made of the fact that the odonate nymph eats mosquito larvæ and pupæ, and the adult dragonfly is an even greater enemy of the mosquito imago. Tillyard (1917, p. 328) stated that he had repeatedly seen Æschninæ feeding upon gnats and mosquitoes in the late afternoon. A specimen of *Telephlebia godeffroyi* was once observed flying round and round a small bush at about 7 o'clock in the evening, when the mosquitoes were particularly troublesome. After 10 minutes it was captured and its mouth was found so full of mosquitoes that it was unable to shut it.

> There must have been over a hundred all tightly packed into a black mass. I have frequently seen *Æschna brevistyla* take gnats and mosquitoes in dozens while on the wing. There can be no doubt that those dragonflies which fly late in the day are of great value in checking the spread of the various objectionable Culicidæ that are on the wing from just before sundown.

Needham and Hart (1901, p. 29) make a similar statement: "The usefulness of the Æschnidæ imagos, especially *Anax junius*, on account of the enormous quantities of pestiferous gnats and mosquitoes which they destroy, puts them among the particular friends of mankind." The Anax imago hunts after sunset, continues flying as long as there is light enough to render its prey visible, and is probably the last dragonfly to go to roost. In its search for food it frequently mounts high up in the air, sometimes disappearing from sight in this manner. The male of *L. luctuosa* has similar habits, but does not carry them quite as far.

Dr. Lamborn (1890) made an investigation to determine the practicability of the artificial use of dragonflies for destroying mosquitoes and flies. While nothing very practical in the way of artificial breeding was suggested, the investigation emphasized the immense service rendered by dragonflies under natural conditions in keeping down these pests.

The members of the family Simuliidæ are even greater pests than the mosquitoes. One species, *Simulium pecuarum*, is known as the southern buffalo gnat and causes the death of many mules and other domestic animals throughout the Mississippi Valley. Another species, *Simulium meridionale*, is known as the turkey gnat, and it also infests all kinds of domestic animals, especially the turkey. "Many cases of the death of human beings from the bites of buffalo gnats have been reported, and some of them seem well authenticated" (Needham, 1903, pt. 2, p. 343). However this may be, all the species are bloodsuckers and intolerable pests, and anything which eats them is thereby distinctly beneficial.

Consequently, even if it could be proved that nymphs had a fondness for young fish, and that they were not themselves of any value as fish food, it would still seem to the present author that the incessant warfare which they wage against gnats and mosquitoes ought to earn them a cordial welcome to every fishpond. It would certainly be better for some of the fish to die than for the pond to become a breeding place for bloodsuckers and disease carriers. And if, in addition to this service, it can be shown, as has been attempted, not only that the nymphs are harmless to the fish as long as they can obtain other food (p. 206), but also that they themselves furnish one of the best of foods for the growing fish (p. 225), they become practically a necessity if fish breeding is to be carried on successfully.

Another positive benefit to mankind is the wholesale destruction of house flies by so many of the odonates. It will be noted that this disease carrier appears as an article of diet in nearly every one of the lists. Æschna is frequently captured while devouring flies on the screens and screen doors of dwelling houses and factories, and Anax has often been reported from similar localities. A list has already been given of those species which came to the laboratory building (100 yards from pond 1D) and picked house flies, Mayflies, and the like off the window screens. In view of the present widespread movement against the house fly conducted by boards of health and hygienists everywhere in the United States, this fly-eating habit of the odonates ought to receive every encouragement.

In this connection also it is worth noting that Dr. G. D. Carpenter, during his investigation of the sleeping sickness in Africa, observed one species of damselfly and two species of dragonflies feeding upon the dreaded tsetse fly, the damselfly even picking them off the clothing of the collector. (Campion, 1914, pp. 498 and 500.)

Another record in this same paper and one by Poulton (1906, p. 399) credit the odonates with eating horseflies (Tabanidæ).

ENEMIES OF ODONATE IMAGOS.

Most authors state that the imagos do not suffer much from natural enemies except during the teneral period, and this appears to be true. But during this teneral period, which lasts for a varying length of time after their emergence from the nymph skin, they are so weak and limp that they fall an easy prey to even the humblest enemies.

1. Accidents.—A small percentage always fails to emerge properly, and in collecting exuviæ one will occasionally be found with the imago only partially emerged. Something prevented it from getting clear of the nymph skin, and it perished in the effort. Again, one or two of the wings may fail to expand properly after the imago has gotten safely out of the skin, and it is then unable to fly and soon perishes. Sometimes the teneral is forced to try its powers of flight too soon, and it falls into the water and drowns. The number of these accidents is probably larger than appears at first, for such drowned imagos easily disappear.

Rain sometimes catches the tenerals before they have become sufficiently hardened to withstand it. Kennedy (1917, p. 530) makes a note of this:

> With many western species the most serious cause of premature death among imagos seemed to be the occasional cold rains which come even in desert regions. On Satus Creek (Yakima County, Wash.) I have seen *Ophiogomphus severus* practically wiped out for the first day or two after a rain and regaining its numbers only after more had emerged.

In the Mississippi Valley a heavy thundershower will sometimes produce the same effect upon the tenerals, the rain fairly sweeping them off their perch and drowning them in the gutters.

Usually those which perish in these different ways, however, form but a small percentage when compared with the innumerable hosts that pass through the metamorphosis successfully.

2. Birds.—*Libellula luctuosa* emerges mostly in the early morning, and for a long time hundreds of teneral wings of this species, easily recognizable by their markings and varnished appearance, were found every forenoon lying on the ground and among the vegetation on the embankments of the ponds. At length the culprits were caught in the very act of seizing and devouring the imagos, and they proved to be English sparrows. They flocked to the embankments at daybreak and hunted through the herbage until they found a teneral; they then seized it, beat its wings off, and either swallowed it or carried it to their young. In this way they destroyed large numbers every day and kept it up as long as the species continued to emerge. When its wings are once hardened, the sparrow can no longer catch the imago, and it is thereafter free from this enemy.

This destruction by the English sparrows is local and apparently casual; in the summer of 1917 they did not destroy as many of the tenerals as in 1916. It seems to be largely a matter of chance; if they happen upon the tenerals at just the right time and get a good meal, they return again and again. The localities frequented by the tenerals are not the ones from which these sparrows are accustomed to get their food, however, and hence there is no systematic hunting for them.

Another bird that causes great destruction among the imagos is the red-winged blackbird. Several pairs of these birds nested about the ponds, and they were seen repeatedly catching the tenerals and eating them or feeding them to their young. A small stake projecting a few inches above the water in pond 2 was a favorite roosting place for one of the male redwings, and from the algæ surrounding this stake were picked up more than 100 teneral wings of *Libellula luctuosa*. During experiments with the large breeding cage mentioned elsewhere (p. 235) adult dragonflies of several species and of both sexes were caught and placed in the cage. Every effort was made to induce them to eat, to mate, and to lay their eggs, but to no avail. One of the chief hindrances was an old male redwing who made it his duty to visit the cage as soon as possible after the dragonflies were placed in it and to pick them off through the wires. In this way he would have them all caught and devoured within a short time.

Kennedy (1915, p. 343) found teneral damselflies and dragonflies in the stomachs of four yellow-headed and one red-winged blackbird which he examined. He also stated on the same page that he believed the yellow-headed blackbirds ate most of the teneral *Anax junius* at one of the ponds where he collected. Other species, such as *Erythemis simplicicollis*, *Æschna multicolor*, and *A. californica* escaped this peril of the birds by emerging late in the evening, so that by daylight the next morning their wings were hard enough to fly.

Both *E. simplicicollis* and *L. luctuosa* roost at night in the tall grass and other vegetation around the ponds, and when there is a rain in the night, or an exceptionally heavy dew, are sometimes so bedraggled in the early morning that they are caught by the birds.

In a later paper Kennedy (1917, p. 530) has noted that *Ophiogomphus morrisoni* at Donner Lake, Oreg., was seriously attacked by robins while emerging.

In the Canadian Entomologist, volume 5, 1873, p. 159, Mr. Gould, in a communication to the Entomological Society of London, said:

> I believe that the larger dragonflies are very liable to the attacks of birds, and have no doubt that the hobby and kestrel occasionally feed upon them; with regard to the small blue-bodied species (Agrionidæ) frequenting the sedgy bank of the Thames, I have seen smaller birds, sparrows, etc., capture and eat them before my eyes after having carefully nipped off the wings, which are not swallowed. This must take place to a considerable extent, as I have observed the towpath strewn with the rejected wings.

The hobby and the kestrel are English hawks, but Fisher (1893) has recorded the swallow-tailed kite, the sharp-shinned hawk, the red-shouldered hawk, the broad-winged hawk, the duck hawk, the sparrow hawk, and the pigeon hawk as feeding on dragonflies here in the United States.

Tillyard (1917, p. 330) has stated that kingfishers are wonderfully expert at catching dragonflies skimming close to the water. That may be true of the kingfishers of Australia and New Zealand, but it is doubtful if our own belted kingfisher of the eastern

United States ever eats them. Shrikes, cuckoos, and kingbirds, however, catch and eat the imagos, even after the wings of the latter have become fully hardened. Hence they are active enemies during the entire adult life of the dragonflies and cause considerable destruction.

3. LARGER IMAGOS.—The imagos of the larger species are great enemies of the smaller species; this is especially true of the gomphids, of Anax, and of Erythemis. All of these were observed eating teneral damselflies and sometimes teneral dragonflies, and these seem to be the favorite food of the female gomphids.

An editorial in Nature, volume 26, 1882, page 89, related a curious fact observed by Signor Stefanelli in regard to a dragonfly (*Æschna cyanea*) often met with near Florence. There were several nymphs of this species in a cistern of water. Some which were almost ready for transformation came out of the water a little way during the night, and attacked several teneral imagos which could not yet fly and voraciously devoured them. It was suggested that this singular practice may explain why one finds such a small number of *Æschna cyanea* in comparison with the number of nymphs. But this is more easily explained by the migration of the tenerals already described (p. 188), and we must regard such a practice as this as extremely exceptional rather than as an ordinary occurrence.

4. ANTS, SPIDERS, ROBBER FLIES, AND FROGS.—These also eat teneral dragonflies, and the spiders capture fully matured adults. Two tenerals of *L. luctuosa* were eaten alive by a colony of black ants on the banks of pond 4. The ants seized them on all sides with their mandibles and tore them in pieces, dragging off the fragments to their nest.

The webs of the common black and yellow spider, Argiope, are thickly scattered through the vegetation along the shores of the ponds, and from them the author secured many specimens of *Ischnura verticalis*, *Enallagma civile*, *E. hageni*, *Argia putrida*, and tenerals of *Sympetrum rubicundulum*, *L. luctuosa*, and *Erythemis simplicicollis*. Williamson (1899, p. 236) has recorded a similar experience in Indiana. A large water spider, common around the shores of the ponds, also catches teneral dragonflies on the grass stems at the edge of the water.

Williamson (1899, p. 235) noted a large robber fly carrying a teneral *Sympetrum rubicundulum*, which it had doubtless killed, and Dyche (1914, pp. 151 to 153) found dragonflies in the stomachs of several large bullfrogs.

The little cricket frog, *Acris gryllus*, is also a confirmed eater of damselfly imagos. His usual roosting place is upon the floating algæ at the surface of the water, where he watches for the damselflies when they come to deposit their eggs. When caught, the damselfly is much longer than the frog's body, but the latter swallows it slowly and keeps swallowing until it has entirely disappeared.

5. PARASITIC MITES AND FLIES.—Tillyard (1917, p. 331) made the following statement:

> Dragonflies whose larvæ live in still water are frequently found covered with the young of a species of small red mites (family Hydrachnidæ). The adult probably attacks the dragonfly at metamorphosis, placing either its eggs or viviparous young on the under side of the thorax, the bases of the wings and legs, or the abdomen, to which they are afterwards found clinging. In this way the dragonfly is used as a means of dispersal by the Arachnid, and the young mites are carried from one pond to another, where some of them drop off.

Ischnura and Enallagma among the damselflies and Leucorrhinia among the dragonflies seem particularly susceptible to these mites. Ten or a dozen of the young mites were found between the wing pads and around the bases of the legs on each of five Ischnura and seven Enallagma nymphs. Forty-four of them were taken from the ventral surface of the thorax of a single female imago of *Enallagma hageni* and 110 were removed from the ventral surface of the abdomen of a single male imago of *Leucorrhinia intacta.* Tillyard said that the young mites cling to the dragonfly without doing it any harm, but in this Leucorrhinia the considerable surface covered by the mites was badly discolored, being changed from black to a yellowish red. The points where each mite was attached were also somewhat swollen and deep red in color, so that the integument seemed to be honeycombed. So far as this particular specimen was concerned, the mites had been obtaining sustenance as well as transportation.

In the family of flies known as Asilidæ there are two genera, Promachus and Lophonotus, which have been seen to capture and eat dragonflies (Poulton, 1906, p. 342).

6. Internal Parasites.—The imagos are susceptible to intestinal parasites as well as the nymphs, and Selys-Longchamps (1850, p. 36) recorded the finding of a Filaria in the abdomen of a dragonfly which inflated it to such an extent as to hinder the insect's flight.

Ssinitzin (1907, p. 24) reported stages of a frog-lung fluke, *Pneumonœces variegatus*, free in the body cavity of both nymphs and adults of the damselfly *Agrion* (*Calopteryx*) *virgo.* By feeding experiments he was able to infect frogs with these forms, showing that the damselfly here serves as an intermediate host for the frog fluke.

7. Sundew and Pitcher Plants.—An observation of Tillyard's (1917, p. 329) is worthy of mention here. He said that in Australia the giant sundew, *Drosera binata*, takes heavy toll of those damselflies which frequent the swamps and marshes. It is doubtful whether any of our North American sundews are capable of capturing damselflies, but our pitcher plants certainly are, and it would be interesting to know if some of them do not occasionally claim odonate victims.

ODONATE NYMPHS AS FISH FOOD.

Evidence from Fish Bait.—The first and most obvious proof that nymphs make good food for fish is the fact that they are used successfully for fish bait. Tillyard (1917, p. 337) recorded that the larvæ of Hemicordulia, called appropriately by the Australians mud eyes, are much sought after as bait for trout and perch. Needham (1903, p. 212) said: "Nymphs attached to hooks were taken by trout, but not more readily than minnows, small frogs, or other bait." He could also probably have said with equal truth that they were not taken any less readily than other bait.

Fishermen in certain parts of the country use nymphs regularly as bait in the same way that "dobsons" are used for bass bait. In Michigan and Minnesota the nymphs are locally called "crabs," and it is said that the rock bass or redeye will take them when it refuses other bait. In the vicinity of Torrington, Conn., the nymphs are known as "perch bait," and boys make a business of catching and selling them to the fishermen. But, of course, the best proof that nymphs serve as fish food is the fact that they are found in goodly numbers whenever the stomach contents of fishes are examined.

Evidence from Stomach Contents.—Prof. S. A. Forbes has made very valuable and extensive studies of the food of fresh-water fishes, of which he published a summary and discussion in 1888. In this paper he gave a detailed list of the stomach contents of many of our food and game fishes, from which we may select those which had eaten nymphs and put them in tabular form. Such a table will be useful as an indication of the kind of fishes for which dragonfly nymphs would furnish acceptable food in pond-fish culture.

Food of Fishes Examined by S. A. Forbes.

Kind of fish.	Period of life of fish.		Number of fish eating—	
	Adult.	Young.	Dragon nymphs.	Damsel nymphs.
Ictiobus bubalus: Small-mouthed buffalo	×	×	4	2
Ictiobus urus: Mongrel buffalo	×		1	
Moxostoma macrolepidotum: Sucker	×			2
Polyodon spathula: Spoonbill cat	×		1	1
Erimyzon sucetta: Common chub		×		1
Amia calva: Dogfish	×		2	
Lucius vermiculatus: Grass pickerel	×	×	6	7
Lucius lucius: Common pike	×		1	
Aplodinotus grunniens: Sheepshead, croaker	×		4	
Aphredoderus savanus: Pirate perch	×		1	
Ictalurus punctatus: Channel cat	×		6	4
Ameiurus nebulosus: Bullhead	×		2	
Labidesthes siculus: Brook silversides	×		1	2
Fundulus notatus: Top minnow	×			1
Hadropterus aspro: Black-sided darter	×			1
Lepomis gibbosus: Common sunfish	×	×	2	2
Lepomis incisor: Bluegill	×	×	5	4
Apomotis cyanellus: Green sunfish	×	×	2	
Pomoxis annularis: White crappie	×	×	1	4
Pomoxis sparoides: Black crappie	×			5
Perca flavescens: Common perch	×	×	5	4
Ambloplites rupestris: Rock bass, redeye	×		1	1
Chænobryttus gulosus: Warmouth bass		×		3
Micropterus dolomieu: Smallmouth black bass		×		2
Micropterus salmoides: Largemouth black bass	×			1
Archoplites interruptus: Sacramento perch	×			1
Fundulus diaphanus menona: Menona minnow	×			1

The numbers in this table seem very small when thus isolated; but if we compare them with the remainder of Forbes's list we find they are comparatively large and are surpassed by those of very few insects.

In his notes he stated that the various nymphs seemed to be most abundant (25 per cent) in the food of the grass pickerel, *Esox vermiculatus*, while they formed from 10 to 13 per cent of the food of the crappies, *Pomoxis annularis* and *P. sparoides*, the pirate perch, *Aphredoderus sayanus*, and the common perch, *Perca flavescens* (1888*b*, p. 485). Hankinson (1908, p. 234) stated that "nymphs were often found in the stomachs of rock bass and blue-spotted sunfish, less frequently in those of the common sunfish;" and in another place: "The nymphs of *Macromia illinoiensis* are much eaten by fishes" (p. 263). In his remarks upon the various species of fish he mentioned nymphs as the food of the bullhead, the rock bass, the blue-spotted sunfish, the common sunfish, the large-eared sunfish, the bluegill, and the large mouth black bass.

Baker (1916) gave the results of his examination of the stomachs of numerous specimens of different kinds of fish. He reported that nymphs of the odonata constituted 25 per cent of the food of one bullhead, *Ameiurus nebulosus* (p. 176); 62 per cent (with caddisflies) of the food of five bluegills, *Lepomis incisor* (p. 182); 15 per cent of the food of one redeye, *Ambloplites rupestris* (p. 182); 30 per cent of the food of one sunfish, *L.*

gibbosus, and 15 per cent of the food of another (p. 187); 60, 75, 85, and 100 per cent, respectively, of the food of four young yellow perch, *P. flavescens* (pp. 192, 193); 6 per cent (with Chironomid larvæ) of the food of six Manitou darters, *Percina caprodes zebra* (p. 194); 19 per cent of the food of four young grass pike, *Esox reticulatus;* and 36.66 per cent of the food of three preadults (p. 201).

Bean (1912, p. 203), in speaking of fish food said: "Important trout foods are snails, dragonflies, mayflies, and caddisflies."

A. S. Pearse, of the University of Wisconsin, in a manuscript paper seen by the present author verifies these observations and adds many other fish species which feed upon odonate nymphs.

Dr. R. A. Muttkowski has very kindly contributed some manuscript notes upon the food of fish from the vicinity of Madison, Wis. The odonate nymphs have been selected from these food data and arranged in the following table:

FOOD OF FISHES NEAR MADISON, WIS., EXAMINED BY DR. R. A. MUTTKOWSKI.

[Numerators represent number of fish in whose stomachs nymphs were found; denominators represent number of nymphs found.]

Kind of fish.	Argia, sp.	Enallagma antennatum.	Enallagma hageni.	Enallagma signatum.	Ischnura verticalis.	Nehalennia irene.	Æschna umbrosa.	Anax junius.	Celithemis eponina.	Libellula luctuosa.	Libellula, sp.
Ambloplites rupestris: Rock bass, redeye		15/24	1/35								
Ameiurus nebulosus: Common bullhead			2/6					1/1			
Ameiurus melas: Black bullhead			3/6								
Lepisosteus osseus: Long-nosed gar		1/1									
Eupomotis gibbosus: Common sunfish			3/5								
Lepomis pallidus: Bluegill		3/5	5/5								
Micropterus salmoides: Largemouth black bass		2/3						1/1			
Perca flavescens: Yellow perch	1/2	18/74	29/202	2/2	5/23	1/1	4/11	2/2	2/4	1/1	1/1
Pomoxis annularis: Crappie			1/1								
Pomoxis sparoides: Calico bass		1/12	9/30		6/89						
Schilbeodes gyrinus: Mad Tom		2/3	2/2								
Umbra limi: Mud minnow										1/1	

Two facts stand out very clearly in this table. The first is that the nymphs of the two species of Enallagma, which are common in the vicinity of Madison, form an important item in the food of the local fish. Every species of fish except the mud minnow has eaten of them in considerable numbers, and for the rock bass and calico bass they seem to constitute the chief item of diet. In all, 24 species of fish were examined, and it is worthy of note that 6 of the 12 which do not appear in this table are found in Forbes's table, where they are simply recorded as eating damselfly nymphs, without any designation of species.

The number of individual perch examined was very much larger than that of any other kind of fish, and the species of odonate nymphs found in their stomachs are correspondingly numerous. They have eaten some of every kind of nymph listed, but their preference seemed to be for the damselflies rather than for the dragonflies, if we may judge by the numbers consumed. At all events, it can easily be seen that odonate nymphs are more toothsome to them than any other single article of diet.

The dragonfly nymphs recorded up to the present time are mostly Libellulides, and it is generally stated that gomphine nymphs escape the fish by burrowing in the sand, the mud, or the accumulated débris of the bottom. But even this burrowing habit does not save them from some fish. Of three spoonbill cats, *Polyodon spathula*, taken at Keokuk in May, 1916, 40 per cent of the stomach contents of one fish consisted of nymphs of *Gomphus notatus*. The second fish's stomach contained 1 *Gomphus vastus* nymph and 1 *Enallagma* nymph, constituting 10 per cent of the food; the third stomach contained 1 *Gomphus vastus* nymph, 25 per cent of the food. Of three moon-eye herrings, *Hiodon alosoides*, one taken March 24, 1916, near Hamilton, Ill., and the other two in June at Keokuk, Iowa, each contained a full-grown gomphine nymph and nothing else. A river drum, *Aplodinotus grunniens*, taken at Keokuk in June, contained a single gomphine nymph, constituting 60 per cent of its food.

Evidence from the fishponds themselves will be more convincing than that from rivers, streams, or lakes, and fortunately there is an abundance of evidence from this very source which furnishes just the proof desired. During the year from June, 1916, to June, 1917, H. E. Schradieck, an employee of the Bureau of Fisheries, was engaged in examining the food of the fishes in the very series of ponds (series D) here considered. Permission has been granted to select from his manuscript records the data relating to odonate food, and these data have been arranged in the following table:

FOOD OF FISHES FROM PONDS IN SERIES D, FAIRPORT, IOWA, EXAMINED BY H. C. SCHRADIECK.

Kind of fish.	Number of fish examined.	Pond from which taken.	Extremes in length.	Average length.	Number containing damsel nymphs.	Number containing damsel imagos.	Number containing dragon nymphs.	Odonate food, 100 per cent.	Odonate food, 75 to 99 per cent.	Average per cent odonate food.[a]	Odonate eggs.
			Mm.	*Mm.*							
Micropterus salmoides: Largemouth black bass	144	3	$\frac{16}{105}$	50	45	2	38	24	38	68.5	......
Micropterus salmoides: Largemouth black bass	136	2	$\frac{16}{92}$	40	51	2	18	8	29	62	......
Micropterus salmoides: Largemouth black bass	20	3	$\frac{8}{22}$	16	1	0	0	0	0	0	......
Lepomis pallidus: Bluegill	103	2	$\frac{20}{60}$	42	29	0	2	0	4	34	......
Ictiobus bubalis: Buffalofish	22	7	$\frac{33}{78}$	51	0	0	0	0	0	0	1
Ictiobus bubalis: Buffalofish	350	5 & 7	$\frac{75}{235}$	......	0	0	0	0	0	0	......
Eupomotis euryorus: McKay's sunfish	120	8	$\frac{27}{64}$	41	18	0	78	14	46	68.5	......
Eupomotis gibbosus: Common sunfish	173	16 B	$\frac{12}{45}$	25	8	0	2	0	0	34	......
Pomoxis sparoides: Calico bass	143	8	$\frac{23}{38}$	30	5	0	1	0	1	41	......
Ictalurus punctatus: Channel cat	5	9	......	9	0	0	0	0	0	0	......
Ictalurus punctatus: Channel cat	21	9	$\frac{45}{95}$	70	......	......	......	......	......	......	......

[a] This average includes only the fish that had eaten odonate food.

The number of fish included in this table is large enough to give considerable weight to the conclusions drawn; a thousand fish stomachs ought to furnish a fairly reliable basis for judgment. Furthermore, the fish have been taken from the ponds during every month in the year except December, January, and February, and thus include as much of the yearly life cycle as is available.

Very small fish do not eat odonate nymphs. Of the largemouth black bass from pond 3 only one, and that the largest of them all, had taken a damselfly nymph; eight specimens of bluegills, averaging less than 10 mm. in length, from ponds 1 and 2, did not show any trace of odonate food; and the five channel cats that averaged only 9 mm. in length from pond 9 had eaten nothing as large as an odonate nymph.

While these small fish refuse the nymphs, they do not refuse the eggs which the dragonflies distribute so freely about the ponds. Of the 22 buffalofish from pond 7D only 1 had eaten dragonfly eggs. But among 59 sunfish from pond 15B, 10 were found to have eaten dragonfly eggs; these 10 fish averaged but 13 mm. in length, the shortest being 10 mm. long and the longest 18 mm. Odonate eggs formed 55 per cent (average) of the food of these 10 fish and reached as high as 98 per cent in one of them. Hence for some kinds of fish odonate eggs will furnish an acceptable food, while the young fry are from 10 to 20 mm. in length.

Judging from the records of the largemouth bass, the bluegill, the common sunfish, and the calico bass, young fish must attain a length of from 22 to 25 mm. before they begin to eat odonate nymphs. From 25 to 40 mm. they take them in comparatively small numbers; from 40 to 100 mm. they eat them in much larger quantities, and often eat nothing else. In every instance where the odonate food constituted 100 per cent the fish was over 40 mm. in length and nine-tenths of them were over 50 mm. From 50 to 80 mm., therefore, may be taken as the size of fish for which odonate nymphs will prove most serviceable as food.

The stomach contents of a largemouth black bass, 80 mm. long, examined July 30, 1917, consisted of three fully grown nymphs of *L. luctuosa*, one fully grown nymph of Erythemis, and the remainder of the food fragments of similar nymphs too far digested for identification.

The small percentage of odonate food in the stomachs of the common sunfish and the calico bass may well be due to the small size of the fish examined. Of the 173 common sunfish included in the table, 96 were under 25 mm. in length and only 32 were 30 mm. or over in length, so that really the 10 fish which ate odonate nymphs were 10 out of 32 rather than 10 out of 173. Similarly, among the 143 calico bass there were only 21 that reached 35 mm. in length, while 100 were between 26 and 34 mm., just the size when they begin to eat sparingly of nymphs. The calico bass does not seem to begin this diet quite as early in life as some of the other fish, although the table of the Madison fish shows that the adults eat damselfly nymphs in goodly numbers. If we remove from the lists here given all the fish 25 mm. in length or under—namely, those that were too small to be expected to eat odonate food—it can readily be seen that the percentage of odonate feeders would be considerably increased.

We may next consider the fish's diet from a seasonal standpoint—the examination of fish food began in the latter part of June and continued through the summer and fall. Both the fish and the nymphs were steadily increasing in size during the period.

By following the charted records—say, of the largemouth black bass, for instance—it is very instructive to note that through June and July, while both nymphs and fish were quite small, the former do not appear in the diet of the latter. The bass began to eat nymphs about the first of August, and during that month in 10 out of the 30 bass examined odonate food reached from 90 to 100 per cent. The fish continued to eat nymphs in large quantities through the fall months. The largest bass was examined September 2 and was 105 mm. in length; 95 per cent of its food consisted of dragonfly nymphs. During the autumn of the first year, therefore, the odonates supply a very large percentage of the food of the young fish, and many fish feed entirely upon them.

Not all fish, however, will take odonate food, no matter how abundant it may be. The two examinations of buffalofish have been included in the table in order to show this fact. The first lot contained fish between 33 and 78 mm. in length, taken from pond 7D and several other ponds not in series D. These fish were all of just the right size to eat freely of the nymphs, judging by the records of the other fish enumerated. But with the exception of one which had eaten a few odonate eggs, probably accidentally, there was an entire absence of odonate food in their diet. Similarly, the 350 larger buffalofish did not show a single instance of the presence of odonate food. We may reasonably conclude, therefore, that such food is not palatable to them and will be of practically no assistance in their culture. It is worthy of note in this connection, however, that Prof. Forbes found both dragonfly and damselfly nymphs in the stomachs of adult buffalofish.

Evidence from Exuviæ.—There are also other methods of obtaining evidence besides an examination of the fish's stomach. Ponds 1, 2, 3, and 4 are as nearly alike as possible in their conditions and environment, but differ considerably in their fish contents. Pond 1 was stocked in the spring of 1916 with about 4,500 small bass and bluegills, while ponds 2 and 3 contained only a comparatively small number of adult bass and bluegills, together with the season's hatch of young, the latter, of course, being too small to eat any nymphs before autumn. There was no appreciable difference in the number of dragonflies hawking and ovipositing around these ponds, but there was a very marked difference in the number of nymph skins obtained along the margins of the ponds. The north shores of ponds 1 and 2 are of the same length and have a border of *Carex stricta* of the same width, but while this border yielded 450 nymph skins on pond 2, only 150 could be found on pond 1. The difference in damselfly skins was even more marked; only 6 were found on the whole margin of pond 1, while a single reed stem in pond 2 yielded 21 skins, and the entire margin yielded a trifle over 500 skins. It would suggest, at least, that the young fish in pond 1 had reduced the numbers of nymphs by eating them, since they were of just the size to eat them freely.

The same fact is even more markedly shown in the case of the Anax nymphs; a few were found in all of the ponds, but when pond 4, containing only adult buffalofish was drawn 200 nymphs were obtained and after the pond was refilled 100 more transformed and left their skins around the margin of the pond. Such disparity in numbers could hardly be due to a discriminating choice on the part of the adults as to the pond in which they laid their eggs.

Evidence from Feeding Nymphs Artificially to Fish.—Best of all, the eating of nymphs by adult fish has been demonstrated by feeding the nymphs directly to them. Pond 6 is the smallest of all the ponds, but it contains the largest number of adult fish, which have been taken out of the other ponds to prevent them from eating the young fish. They get hungry in this small pond and have to be fed at times. Among the foods given to them have been dragonfly nymphs, *Anax junius* and *L. luctuosa*, obtained from other ponds when the water was drawn from them. The fish in pond 6 always eat these with avidity, consuming all that are thrown to them, sometimes several hundreds.

This fact carries with it several suggestions as to the methods of dealing with these nymphs. Whenever a pond is drained, as many of the nymphs as possible should be saved for further use. If the water is lowered gradually, the nymphs, like the fish, will follow it down to the last pool, from which they can be easily removed with a dip net. They can then be used to restock the pond from which they came, after it is filled again, or they can be fed to the fish in other ponds.

Atkins in a discussion of Foods for Young Salmonoid Fishes (1908) said: "Any departure, therefore, from a live-food regimen must be regarded as having the presumption against its entire stability" (p. 841); and, again quoting from the Allgemeine Fischerei Zeitung, "for breeding fishes under all circumstances live, natural food is the most suitable" (p. 841).

Here is a live-natural food that can often be obtained in large quantities and of various sizes suited to the different growths of fish, and methods of stocking a pond with this kind of food will be discussed later (p. 234).

ODONATE IMAGOS AS FISH FOOD.

The only time that a fish gets a chance to catch a dragonfly imago is during ovipositing. The Argia females that back down beneath the surface of the water to deposit their eggs must face the danger of being snapped up by some hungry fish, and many of them are probably caught at such times. (See p. 257.) The same will be true of other damselfly species, since most of them alight on something at the surface, and at least thrust their abdomen into the water while ovipositing.

Both bass and sunfish jump eagerly after ovipositing dragonflies, but, like Williamson, the present author has never seen a fish actually catch one of them. However, on opening the stomachs of bass from pond 6 that had been killed for experimental purposes dragonfly imagos were found in more than half of them, showing that at times they are successful in their efforts. Several times the author caught dragonflies in the net, crippled their wings so that they could not fly, and threw them on the surface of pond 6. In almost every instance they were seized and swallowed as soon as they struck the water, but two or three that failed to wiggle after hitting the water were left untouched. These fish would not snap at dead food of any sort, and they came up to these dragonflies until their nose almost touched the insect and waited patiently for some movement indicating life. If the dragonfly wiggled ever so little it was swallowed instantly, but if it remained motionless it was left untouched.

Tillyard (1917, p. 330) has the following record: "A 2-pound trout which I caught on the Macquarie River in Tasmania had in its stomach the undigested heads of 35 dragonflies, 28 belonging to the rather rare species *Procordulia jacksonensis*."

In the record of fish food given to the author by Dr. Muttkowski are two instances of fish eating imago damselflies. (See table, p. 227.) The stomach of a black bullhead, *Ameiurus melas*, contained 6 *Enallagma hageni* imagos, and the stomach of a largemouth black bass contained 22 *Enallagma antennatum* imagos.

In a record made by Mr. Schradieck of the food of the largemouth black bass in ponds 2 and 3 D, a fish 48 mm. in length had for its stomach contents 95 per cent damselfly imagos and 5 per cent Chironomid larvæ. Another fish, 82 mm. long, contained nothing except a few damselfly imagos; a third, 65 mm. long, contained 50 per cent damselfly imagos and 20 per cent odonate eggs.

H. L. Canfield, superintendent of fish culture at the Fairport station, told the author that he had fed Anax imagos to largemouth black bass at Homer, Minn. The fish seized them avariciously and apparently swallowed them, but in a moment or two spit them out again. Perhaps the Anax was too large a mouthful for them, for the bass at Fairport certainly swallowed imagos of *L. luctuosa*, Erythemis, Plathemis, and Leucorrhinia and kept them down.

STOCKING THE FISHPOND.

Having tried to show, it is hoped with some success, that dragonflies and damselflies and their nymphs are not only desirable additions to the fauna of fishponds but that they may even prove of considerable importance, there remains the problem of obtaining a sufficient number of the right kind with which to stock a pond. How can this best be accomplished? With reference to the dragonflies several methods may be suggested and briefly discussed. Embody stated in The Farm Fishpond (1915, p. 242) that after the pond has been completed and filled with water:

> The aquatic plants should be the first organisms to be put into the pond * * * The forage animals should be collected next. As has been stated, until more is known about the propagation of aquatic insects it will be impossible to give definite and reliable directions for their introduction. Certain desirable forms will naturally be attracted to the pond for egg laying, and for the present this natural method of propagation is the only one to be depended on.

Of course dragonflies will be among the insects naturally attracted to the pond for egg laying, but it is desired that the pond be stocked at once and with the kinds most available for forage food. The author believes that, so far as the odonates are concerned, we already possess sufficient knowledge to enable us to take the initiative, and not only to introduce desirable species, but also to exercise considerable control over their subsequent abundance.

CHOICE OF DRAGONFLY SPECIES.—The species of dragonfly best suited to any particular fishpond is not by any means necessarily the one that has been tried successfully elsewhere. The condition of the pond and its environment will have as great an influence upon the dragonflies as upon the fish with which it is stocked. In general, a common local species of dragonfly will be far better than one imported from a distance. A visit to neighboring ponds and quiet streams and a careful comparison of their conditions and surroundings with those of the proposed fishpond will be the proper method of choosing the species. Find a place as close to the fishpond and as similar to it as possible, and use this as the source from whence to obtain the stock material.

In 1889 Dr. P. R. Uhler, at that time one of the best authorities upon the dragonflies, wrote the following to Dr. Robert H. Lamborn (1890, p. 12) in reference to the breeding of dragonflies for the purpose of killing off mosquitos:

> As I have raised all the common forms of our Atlantic coastal-plain region, I know that the dragonfly larvæ can be reared in vast numbers. Of course, you know that each locality supports its own species,

and the forms which develop in the brackish drains and pools near tide, where they are covered twice each day by salt water, can not flourish in fresh water. Accordingly, for the littoral belt from Long Island to Beaufort, N. C., I would select *Diplax* (*Erythrodiplax*) *berenice*, *Libellula auripennis*, and *Mezothemis* (*Pachydiplax*) *longipennis*. For the region next inland from this multitudes of common species could be had, such as *Anax junius*, *Æschna* (*Epiæschna*) *heros*, *Libellula pulchella*, *L. luctuosa*, *L. semifasciata*, *Plathemis trimaculata* (*lydia*), and most of the species of Diplax (Sympetrum). On the clear streams which rush down from the hills Cordulia, Epitheca (Epicordulia), and Gomphus prevail.

The above statement is just as good to-day as when it was written, only we must extend the area west of the Allegheny Mountains to cover the entire breadth of North America, and we must include damselflies as well as dragonflies. For the region east of the Alleghenies good damselflies would be *Lestes rectangularis*, *Ischnura verticalis*, *I. posita*, *Enallagma civile*, *E. hageni*, and *Anomalagrion hastatum*.

For the Mississippi Valley some of the desirable odonate species would be *Anax junius*, *Æschna constricta*, *Epicordulia princeps*, *Tramea lacerata*, *Libellula luctuosa*, *L. pulchella*, *Erythemis simplicicollis*, and *Plathemis lydia*, and local species of Argia, Ischnura, Enallagma, and Lestes.

West of the Rocky Mountains, Anax, Erythemis, Tramea and Plathemis would still remain, the species of Æschna and Libellula and of the four genera of damselflies could simply be changed to suit the locality, and Sympetrum could be added.

High up among the mountains Anax and Sympetrum, *Libellula quadrimaculata*, and *Leucorrhinia glacialis*, with local species of Enallagma and Lestes, would be most suitable.

It will appear at once that certain of the desirable forms, such as Anax, *L. pulchella*, *P. lydia*, and the damselfly genera Argia, Enallagma, and Lestes are very cosmopolitan, and their wide distribution increases by so much the chance that they will succeed wherever they may be introduced. They constitute, therefore, the very best stock material available, but still demand certain conditions if they are to be reared successfully. For example, the Anax female inserts her eggs into the tissue of the stems of water plants, and hence cat-tails, arrowhead, rushes, or some such water plant must be provided if this dragonfly is to breed in any numbers. On the other hand, Erythemis takes most kindly to floating blanket algæ; the damselflies insert their eggs in the stems of all kinds of water plants, occasionally above the surface (Lestes, etc.), though usually below it, the female sometimes descending several inches beneath the water for ovipositing.

The dragonfly genus Epicordulia deposits its eggs in long ropes of jelly coiled about the stem of some convenient water plant, while the great majority of the Libellulids deposit their eggs anywhere in clear water by hovering over the surface and repeatedly striking the water with the tip of the abdomen. In the latter case the eggs sink to the bottom separately and are fastened by the jelly that surrounds them to anything they may come in contact with. Hence for these different odonates the fishpond must contain water plants, with stems both above and below the surface, floating algæ, and plenty of open spaces.

PREPARATION OF THE POND.—No special preparation is required, because when a pond is suitably prepared for fish it will contain the requirements just enumerated and will be ready also for the dragonflies. While the condition of the embankments around the pond can not affect the fish or the nymphs in the water, it can and does exert an important influence on the odonate imagos. A total absence of trees, shrubs, bushes, and weeds, with close-cut turf extending to the water's edge, may add to the sightliness of the pond, but it will operate against the odonate fauna. The larger vegetation is not necessary; an area covered with tall weeds and grass somewhere around the margin of the pond will prove amply sufficient.

If the breeding of fish and the rearing of forage for their consumption is confined to a single pond, of course that will be the place to stock with odonate eggs or nymphs. With proper care such combined breeding may be carried on successfully in the same pond, as is done at Fairport. "If not overstocked, the average pond may be managed so that it will furnish all the live food necessary for the adult fish." (Johnson and Stapleton, 1915, p. 19.)

In the last few years the forage problem in connection with fish culture has been receiving much more attention here in the United States. Embody (1915, p. 233) noted that "The propagation of minute organisms in great numbers as food for young fishes has been accomplished by the Chinese and the Japanese and more recently by the Germans," and he recommeded small forage ponds in connection with the larger fish pond (p. 235):

> There is good reason for believing that the supply of aquatic insects can be materially increased by building a few small breeding ponds along the margin of the main pond and excluding all fishes therefrom. Certain insects will naturally deposit their eggs in both breeding and main ponds. There are no very destructive insects in the former; hence there are sure to emerge a goodly number of adults, which, in turn, will continue year after year to repopulate the small ponds, as well as the main pond.

Needham and Lloyd have advocated the same idea in The Life of Inland Waters (1916). In figure 242, on page 408, they present a diagram illustrating conditions advisable for intensive fish raising on an 80-acre tract of wet upland traversed by a trout stream. The noticeable thing about it is the large area, 40 acres of ponds, to be placed under control for the production of fish forage.

Until experiments have been tried out in a practical way for some length of time, it will be impossible to decide definitely how much breeding area is necessary or advisable in order to produce the amount of food forage requisite for a given number of fish. Meanwhile, if forage breeding is to be attempted, the place to put the odonate eggs and nymphs will be with the other fish food in the breeding ponds, as well as in the main fishpond. Once well started in both places they will thereafter propagate themselves, as Embody has stated.

Securing the Stock Material.—The method of securing the necessary odonate eggs or nymphs for stocking the pond will vary with the time of year. If the fishpond is to be started in the spring or fall, the best odonate material to put in it will be the nymphs These may be collected from the nearest pond or from the still water of a stream or river Some nymphs inhabit running water or places where there is a perceptible current, but such species are not suited for pond life.

An old ditch well choked with algæ and water plants, and in which the water stands throughout the year, is an admirable source whence to obtain the nymphs. There are two good methods of collecting them, and it would be well to use both. If there is much loose algæ and débris over the bottom of the ditch, the best implement to use is the common garden rake, as advised by Needham (1899). The collector can stand on the shore and rake the algæ and weeds out of the water onto the ground in front of him. As the water drains off the nymphs will make active efforts to get back, and are thus easily found and secured.

If there is more mud than water plants, the best implement is a sieve net like the one recommended by Needham and shown in figure 37*a*. With this the mud and silt can be drawn ashore and there sifted out, the mud escaping while the nymphs are retained. Much of the material pulled in by the rake can also be advantageously put through the sieve. Needham's sieve net had a framework of steel rods, sides of galvanized iron, and a bottom of galvanized-wire screen. If something of this sort can not be readily obtained or manufactured, the following may be substituted: Bend a piece of large and stiff wire 3 feet long into the shape of a stirrup, the ends coming together at the center of the curved side. Weld the ends together and insert them with a ferrule into a stout handle 6 or 7 feet long. Make a bag out of bobbinet and fasten its mouth securely to the wire stirrup. The mud will sift through this net as well as through the wire screen, but of course the net can be torn easily. Armed with such a net and a rake, a boy can easily secure several hundred nymphs in a few hours. Needham records that he once collected enough nymphs of *Gomphus descriptus* to fill a quart fruit jar from Six Mile Creek near Ithaca, N. Y., in an hour's time (Needham and Betten, 1901, p. 453). The only objection to this method of stocking a fishpond is the fact that no one but a scientific expert can distinguish between the different nymphs obtained. They must all be put into the pond together, good, bad, and indifferent; but there are likely to be plenty of the desirable species among them, and the rest can be safely ignored.

In the summer the pond can be stocked much more intelligently by obtaining the eggs of desirable species and hatching them. In the case of the dragonflies this can not be done by capturing the adults and breeding them artificially or in captivity, as is the unanimous testimony of all who have made the attempt.

A. C. Weeks, at that time secretary of the Brooklyn Entomological Society, made in 1889 an extensive experiment with *Libellula pulchella* and *Diplax* (*Sympetrum*) *rubicundulum* by catching the full-grown adults and confining them in the upper story of his dwelling house, which had been cleared of its furniture and arranged with a view to attract the dragonflies. But they would neither feed nor mate nor oviposit. The same experiment was tried later on *Anax junius* with equally negative results (Lamborn, 1890, p. 78). This was in a crowded city, however, and it might well be supposed that the insects were distracted by the surroundings.

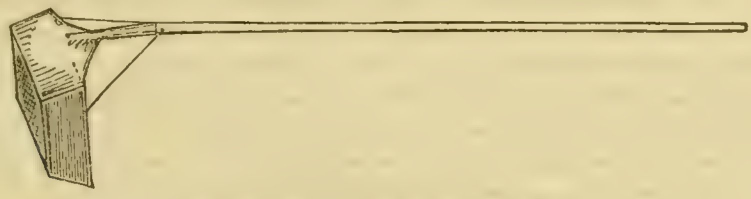


FIG. 37*a*.—Sieve net recommended by Needham.

To test this, the present author experimented with a breeding cage large enough to allow great freedom of motion under conditions that were ideally natural, except for the single element of restraint. This one thing proved a fatal stumbling block, and, although both sexes of *Libellula luctuosa*, *L. pulchella*, *Erythemis simplicicollis*, *Leucorrhinia intacta*, and *Anax junius* were placed in the cage at different times, they were all immediately imbued with an overwhelming desire to escape. The cage was open at the bottom and was put down over a section of pond 3D containing cat-tails, reeds, algæ, and other water plants, everything being left undisturbed. The upper portion of the cage was covered with chicken wire whose meshes were large enough to allow free access to the insects upon which the dragonflies usually fed. But as soon as the dragonflies found they were shut in, they would neither alight on the water plants, nor touch the insects that flew through the cage, nor mate, nor oviposit. Instead, they spent their time beating their wings against the sides and top of the cage until they became exhausted and fell into the water, or were picked out through the meshes of the wire by red-winged blackbirds, which were attracted by the beating of the insects' wings.

While the dragonflies are thus averse to breeding in confinement the damselflies take kindly to it, and Balfour-Browne (1909) succeeded in obtaining a large number of eggs from specimens of two English species, *Agrion pulchellum* and *Ischnura elegans*, which he kept for a week in a cage. He fed the captives on flies and other insects captured in a sweeping net and placed alive in the cage. The eggs hatched into nymphs in about three weeks, so that he was able to determine definitely the period of incubation for these species. This method was not tried on our American damselflies, but there is little doubt that it would work as well with them as with the English species. It was found absolutely necessary to keep the cage in the bright sunlight, because in the shade and on dull days the damselflies became torpid and simply clung to the sides of the cage. It is evident, therefore, that nothing can be accomplished by endeavoring to breed dragonflies in this manner; their natural habits and instincts are against it. And although the damselflies are more susceptible to captivity, this artificial breeding is a rather laborious process for any except the scientific expert who wishes to absolutely isolate a given species.

Fortunately there are other ways of accomplishing the desired results, and these prove to be highly successful. As already stated, many female dragonflies deposit their eggs loosely in the water or upon the floating algæ by hovering close to the surface and touching the water at intervals with the tip of the abdomen. If such a female be caught as she comes down to the pond to lay her eggs or while she is ovipositing and one pair of wings be folded together over the back and held between the thumb and forefinger, leaving the other pair free, she will continue to lay eggs in large numbers if the tip of her abdomen be dipped in water in a convenient tumbler, basin, or small jar. Tillyard (1917, p. 358) claimed that it was "necessary to have the water dirty, with mud, sand, or small pieces of débris for the eggs to fall upon; otherwise the eggs will simply all stick together and quickly go moldy." While agreeing that the presence of dirt is a positive advantage in the way that Tillyard suggests, the present author can not agree that it is always "necessary." All the experiments hereinafter recorded were made in clean water, and while the eggs usually did stick together, they did not mold except in a single instance, and even then practically all of them hatched. However, if the nymphs are to be used simply to stock the fishpond, some dirt and débris are desirable, since then the conditions are more nearly natural. Similarly, when the male accompanies the female during ovipositing, on being captured the female will deposit her eggs freely in the tumbler or basin; this applies to such species as Tramea and Celithemis.

Needham recorded a female *Gomphus graslinellus* captured while ovipositing, from which he "obtained in a tumbler of water an immense number of eggs" (Needham and Hart, 1901, p. 69). Also a female *Gomphus externus*, "captured in the weeds at the bank (Illinois River) deposited for me in a watch glass of water in a few minutes' time about 5,200 eggs. This number is an estimate from a partial count" (p. 75).

The present author stood in one spot on the bank of pond 4D and captured within half an hour six *L. luctuosa* females as they came to the pond to oviposit and from them fully 4,000 eggs were obtained.

For stocking purposes the eggs of the different species do not need to be kept separate. On another afternoon females of *L. luctuosa*, Erythemis, and Leucorrhinia were allowed to deposit their eggs in the same tumbler and all hatched out together without apparent trouble.

Armed then with an insect net and a convenient receptacle, thousands of eggs can be easily obtained in a short time at any place where the dragonflies are ovipositing and only the eggs of desirable species need be taken. These eggs can then be carried to the pond and placed loosely upon the bottom or on the floating algæ, care being taken that they do not get buried in silt or mud, but remain on the surface; or they can be kept in the original receptacle until they hatch, and then the nymphs can be turned loose in the pond, not all in one place, but well distributed. The number of nymphs obtained in this way need only be limited by the patience of the collector.

If the eggs are allowed to hatch before being placed in the fishpond, care should be taken that they do not require a long transportation. Mrs. Aaron gave this warning: "The question of transporting the young larvæ from the breeding tanks to the mosquito-infested ponds is to be considered. Although they are tough and can stand jolting, only a few can be carried in one receptacle. Twenty put in one jar would be found to be an inextricable, kicking mass of cannibals after a mile's transportation" (Lamborn, 1890, p. 63). While perhaps transportation for a mile would produce this result, no difficulty has been experienced in carrying thousands of newly hatched nymphs from the laboratory to the fishponds, a distance of 500 yards.

Anax, Æschna, and the damselflies insert their eggs by means of an ovipositor into living or dead vegetable tissue either beneath the water or resting upon its surface. The females of these species can be watched while ovipositing and after they have finished the leaves or stems containing the eggs can be removed and transferred to the fishpond or they may be kept in water until they hatch. These females will not deposit eggs in a tumbler or basin, like those previously mentioned, but just as many can be secured by gathering the vegetation containing them.

Sufficient experience might enable one to distinguish between the eggs of different species, but ordinarily the vegetation must be transferred to the fishpond with all the eggs it may happen to contain. It is surprising, however, to find how often it proves that practically all the eggs in a single leaf or stem are those of one species.

Females of *Enallagma hageni* were observed inserting their eggs in the tissue of crex-grass leaves that had fallen into the water. Five of these leaves that contained fully 1,500 eggs were obtained, and these were cut into short lengths and kept in tumblers of water until the eggs hatched. Similarly, *Argia mœsta putrida* was observed descending a small water-soaked branch of willow near one of the wing dams in the Mississippi River in order to deposit its eggs, the female dragging the male down with her during the process. On pulling the branch out of the water a dozen couples of this damselfly flew off from it at varying depths, and the softened wood was found to be literally filled with eggs for a distance of 2 feet. A partial count and an estimate of the remainder indicated at least 2,000 eggs in this one branch. It also was cut into short lengths, and these were kept in tumblers of water until they hatched.

The damselflies will breed and deposit their eggs in captivity as already mentioned. (See p. 236.)

REARING THE NYMPHS.—The best method of caring for the nymphs is to place them in the fishpond as soon as they are hatched. Conditions might arise, however, which would render it desirable to rear the nymphs to a certain size before using them for fish food. And this can be easily accomplished by supplying them with requisite food.

The first lot (about 350) of nymphs of *L. luctuosa* that were hatched in the laboratory were kept throughout the entire season in a small aquarium. They were fed every two or three days with ordinary tow obtained from the river or one of the ponds. They seemed particularly fond of the minute crustacea and devoured large numbers of copepods, daphnids, and cladocerans.

Balfour-Browne fed his newly hatched nymphs upon Paramœcium, which he obtained by making an infusion of horse dung in water. One jar of this infusion produced for five or six months enough Paramœcium to supply all his nymphs. As the nymphs grew in size the Paramœcia were replaced by Daphnids, and in this way he carried the nymphs of *Agriom pulchellum* and *Ischnura elegans* through from the egg to the imago stage.

Warren placed individual nymphs in separate petri dishes as soon as they were hatched and fed them on newly hatched mosquito larvæ until the third or fourth molt. They were then transferred to larger dishes and fed on larger mosquito larvæ. In this way he carried four nymphs of *Pantala flavescens* successfully through their entire life history from the egg to the imago. Two of them were fed daily with large amounts of food, and they transformed into the imago stage in about two months. The other two were given much less food, and in consequence they required over three months for their development.

EXPERIMENTS IN HATCHING ODONATE EGGS.

There are but few records of the length of time spent by American dragonflies and damselflies in the egg state. Wm. Beutenmuller (Lamborn, 1890, p. 125) stated that *Libellula auripennis* and *L. pulchella* deposit 25 to 40 eggs each time the female dips her abdomen beneath the water. He added on the next page that eggs laid by *L. pulchella* July 23 hatched August 31, making the period of incubation 39 days. In *L. auripennis* the interval was only 8 days, in *Plathemis lydia* 10 days, and in *Diplax (Erythrodiplax) berenice* and *Sympetrum rubicundulum* 10 days.

Among the damselflies Needham (1903, p. 229) said of Lestes in New York State: "The eggs, deposited well above the water, develop normally from the first, and in the course of two or three weeks attain a condition which is apparently almost that in which they will hatch. They then estivate through the remainder of the summer and early autumn till the pools are refilled, and the stem and leaves, now dead, fall into the water." Eggs laid in July and gathered in October hatched within a week in his laboratory. But of course such a record would not apply to other genera and species where there is no estivation.

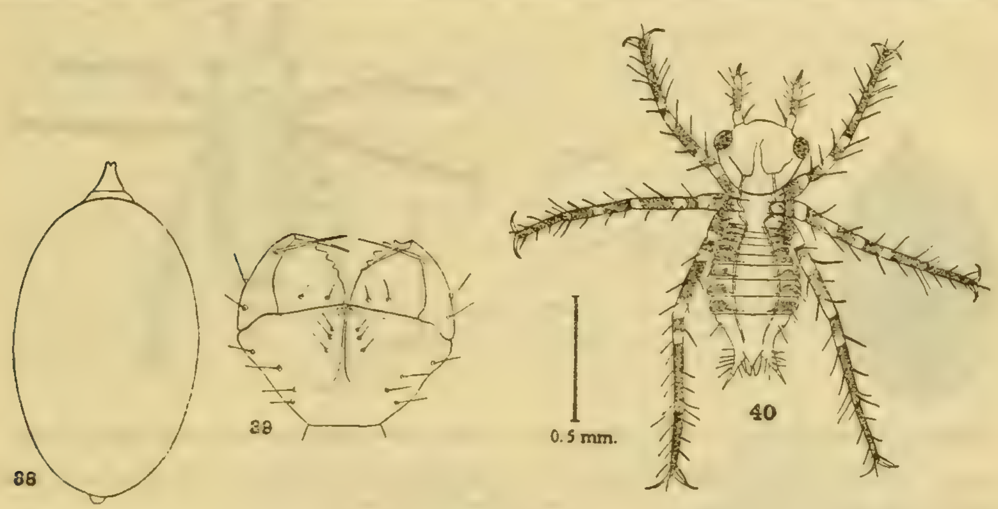
In view of the meagerness of American records, the following experiments at Fairport are recorded as a partial guide for the fish breeder, and there are also included descriptions and figures of the eggs and newly hatched nymphs to help in identification.

LIBELLULA LUCTUOSA.

The Egg.—The egg of this species is an almost perfect ellipse, 0.57 mm. long and 0.30 mm. wide. The neck is conical, as wide at the base as it is high, with a distinct basal segment and a divided tip. There is also a short process at the posterior end of the egg; the yolk granules are comparatively large and distinct. Eggs laid on July 12 began to hatch July 22, and the hatching was entirely completed by July 30. Several lots of eggs from this species were hatched during the summer, and the period of incubation was practically the same for each lot.

The Nymph.—The newly molted nymph is just 1 mm. in length, exclusive of the antennæ; the head and abdomen are the same width, 0.38 mm.; the head is one-fifth wider than long; the hind legs are about the same length as the body, the first two pairs are proportionally shorter; the antennæ are a little shorter than the head and rather stout. The head is a deep, sulphur yellow, the eyes are dark orange, with black spots, the digestive canal is light yellow, and the legs are banded with gray and white.

As soon as the pronymph has molted and becomes a true nymph, the latter swims up to the surface of the water, accomplishing this locomotion by means of the legs, without any help from water ejection at the rectum. Having reached the surface the nymph is able to hold itself there by clinging to the surface film with its claws. It remains there for a long time almost motionless, so that, if the tumbler be examined at any time, the undersurface of the water film will be found covered with nymphs as close together as they can stick. It often happens that one coming up from the bottom finds another already clinging to the film when it reaches the latter. It then fastens to the other nymph instead of to the film, and the combined weight of the two nymphs is more than the film can sustain, so that they sink slowly back to the bottom. Under natural conditions such a seeking of the surface brings the nymphs to the floating algæ or other surface vegetation, which is evidently the location they seek for safety and food. It is also possible that the young nymph, like the teneral imago, needs the stronger sunlight for hardening its chitin integument and maturing its color pattern.



FIGS. 38 to 40.—Development of *Libellula luctuosa:* 38, egg; 39, mask of newly hatched nymph; 40, newly hatched nymph.

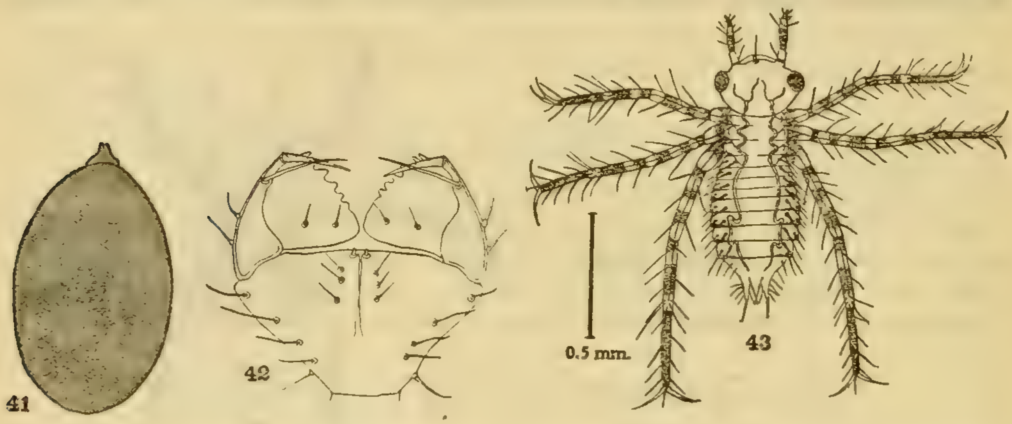
The Mask.—Mentum twice as wide as long; distal margin two times the length of the proximal; four setæ on the inner surface along either side near the lateral margin; three mental setæ on each side of the center in a straight line; a toothed prominence on the midline behind the distal margin. Lateral lobes one-half longer than wide; two marginal setæ on the outer border near the base; two laminate setæ on the blade of the lobe near the inner margin; raptorial seta just reaching the tip of the movable hook, the latter long and slender; distal border of lobe with five teeth near the outer corner, the second tooth the longest.

LIBELLULA PULCHELLA.

A pair was taken mating on the north shore of pond 4D, and the female deposited 1,500 eggs. These eggs were laid July 12; they began hatching July 22, and the hatching was completed by July 28.

The Egg.—Curiously enough, the egg of this large species is smaller than that of the little Leucorrhinia. It is ellipsoidal in form, measuring 0.48 mm. in length and 0.29 mm. in width. The neck is conical, the base nearly twice the height and without any visible segment, but the tip is divided; there is no process at the posterior end of the egg. The yolk granules are small and indistinct.

The Nymph.—This nymph is also just 1 mm. long; the head is one-third wider than long, one-fourth the entire length; the abdomen is as wide as the head, with two rows of stout bristles on the dorsal surface along either lateral margin; the latero-posterior appendages are very hairy. The antennæ are long and slender, black at the tips, with a single black band on the basal joint; the legs have black and white bands, as shown in the figure; the eyes are straw yellow, with two larger black dots and concentric rows of smaller ones; the head between the eyes and whole body is a pale yellow, deepening into orange over the gizzard and rectum; there are whitened areas along the sides of the abdomen at the posterior margins of segments 4 to 7, with darker areas anterior to them. The base of the antennæ is whitish, with a black distal band; first joint proximally gray, distally whitish; second joint nearly all dark gray, with a narrow, white distal band; third joint dark gray, except the very tip, which is whitish. The whole body is transparent and pale white, a little yellowish on the head and at the posterior end of the abdomen; the circulatory system is deeper white.



FIGS. 41 to 43.—Development of *Libellula pulchella:* 41, egg; 42, mask of newly hatched nymph; 43, newly hatched nymph.

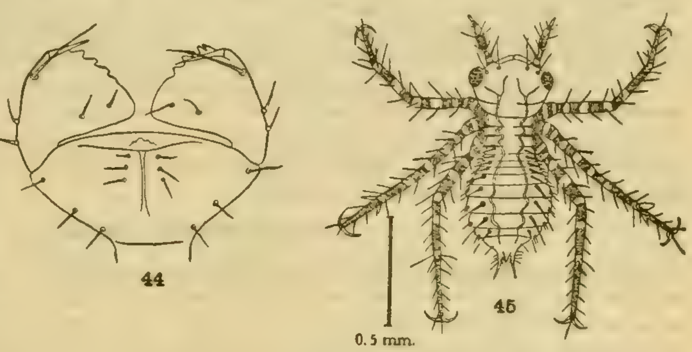
The Mask.—Mentum three-quarters wider than long, distal margin two and a half times the length of the proximal; four setæ on the inner surface, near the lateral margin, one proximal to them on the margin itself; three mental setæ on either side in nearly a straight line; two tiny spines at the center, near the distal margin. Lateral lobes one-fourth longer than wide; two setæ on the outer margin, near the base; two setæ on each blade; raptorial seta longer than the movable hook, the latter long and narrow; distal margin with six teeth near the outer border, the first two the longest.

HYBRID BETWEEN LIBELLULA PULCHELLA AND L. LUCTUOSA.

A male *L. pulchella* and a female *L. luctuosa* were captured mating on the shore of pond 4D July 9, 1917. The female deposited about 100 eggs in a tumbler of water, and these subsequently hatched on July 20.

The Nymph.—This nymph is unlike those of either pulchella or luctuosa, especially in its markings. The head is one-third wider than long, and the same width as the abdomen, grayish yellow; the eyes are sulphur yellow, with small black retinal dots; the rest of the body is pale yellowish, but without much color and quite transparent, except along the lateral margins of the abdomen, where each segment is dark gray anteriorly and white posteriorly. The whole body is quite hairy, with a row of stout bristles along the dorsal surface of the abdomen, between the respiratory system and the lateral margin on either side. The antennæ are relatively large; base white with a pale grayish distal band; first joint white through the center, pale grayish at either end; second joint with proximal three-fifths dark and distal two-fifths white; third joint dark, tipped with white. These nymphs did not ascend to the surface of the water, like those of *luctuosa*, but stayed down near the bottom of the tumbler.

The Mask.—Mentum twice as wide as long; the distal border two and a half times the proximal; the lateral margins curved; three setæ on either side, near the lateral margin; three mental setæ in a straight line; a slight lobed prominence behind the center of the distal margin, without spines. Lateral lobes one-third longer than wide; two setæ on the outer border near the base; two on each blade; raptorial seta considerably longer than the movable hook, the latter short and slender; distal margin with four teeth near the outer edge, the first two the longest.



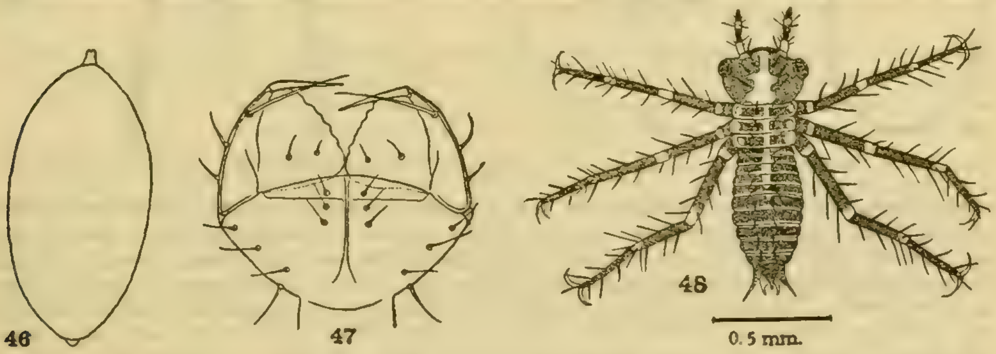
FIGS. 44 and 45.—Hybrid from male *Libellula pulchella* and female *Libellula luctuosa:* 44, mask of newly hatched hybrid nymph; 45, newly hatched hybrid nymph.

ERYTHEMIS SIMPLICICOLLIS.

The first females were seen laying in pond 4D on July 12, 1917. Eggs laid July 13 hatched July 23.

The Egg.—The egg of this species is an elongated ellipse, with rather pointed ends, and is a little more than twice as long as wide, the respective diameters being 0.60 mm. and 0.27 mm. The neck has a base narrower than its height, divided at the tip; there is a small process on the posterior end of the egg; the yolk granules are minute.

The Nymph.—This nymph has the most pigment of any of those examined, and is banded brown and yellowish white; the eyes are light orange yellow with comparatively large black spots; the sides of the head are brown shading into light yellow on the median line; each thorax segment is brown bordered with dark yellow along the lateral margins and light yellow in the center, thus leaving a clear yellow longitudinal streak through the center of the body; the ninth and tenth segments are yellow; the legs are dark proximally, with a white band across the distal ends of the coxæ, femora, and tibiæ. The central yellow line of the head passes over the forehead and down between the antennæ onto the labrum. On the back of the head it is widened considerably and usually runs out into two rounded points on either side, with two small, brown spots, one on either side of the midline, at the level of the posterior points. Through the thorax it is narrow, then widens again on the first three or four abdomen



FIGS. 46 to 48.—Development of *Erythemis simplicicollis:* 46, egg; 47, mask of newly hatched nymph; 48, newly hatched nymph.

segments, and fades into small, yellow dots on the anterior margins of the fifth, sixth, and seventh, and sometimes the eighth, segment, disappearing entirely on the ninth, and often on the eighth segment. The dorsal appendages on the tenth segment are light brown at the base, yellow at the tip; the lateral and inferior appendages are dark brown. The base of the antennæ is yellow distally and proximally with a narrow, black band through the center; first joint dark, with a narrow, distal, white band; second joint with a broader, distal, white band; third joint entirely blackish brown.

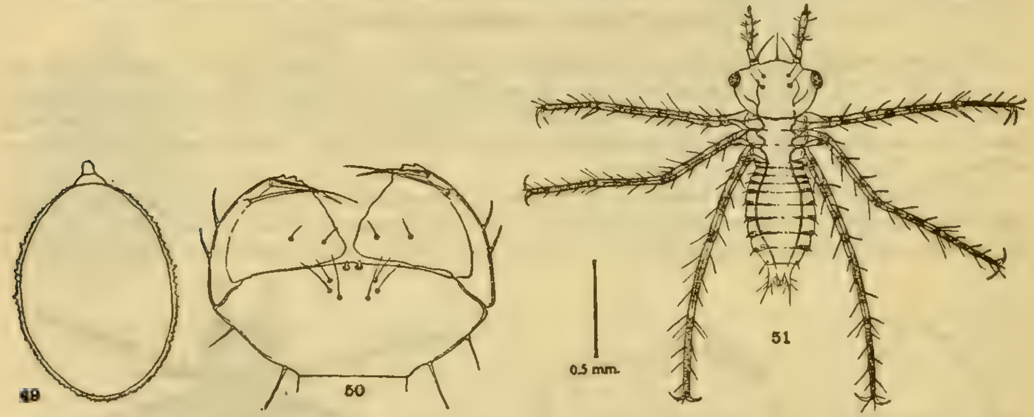
The Mask.—Mentum with the width to the length as 5 to 3, distal margin two-thirds wider than the proximal; three lateral setæ, one marginal seta; three mental setæ in a straight line on either side of the center. Lateral lobe with its length to its width as 9 to 7; two marginal setæ on the outer border; two setæ on the blade of the lobe; raptorial seta just reaching the tip of the movable hook, the latter long and stout; distal margin crenate, without teeth.

LEUCORRHINIA INTACTA.

The sexes remain in union only a short time and usually alight on some convenient weed or bush near the water's edge, where they can be easily secured. When thus captured, the female is ready to lay as soon as taken from the net and will deposit 100 to 200 eggs, the first 50 or 75 coming in a mass stuck together, the others coming singly. Eggs laid July 18 hatched July 30.

The Egg.—This egg is more nearly spherical than that of *Libellula luctuosa*, and has diameters of 0.60 mm. and 0.40 mm., respectively. The neck is wider at the base than it is high, and there is a distinct segmentation at about the center; the tip is not divided, and there is no process on the posterior end of egg. The yolk granules are comparatively large, and the jelly envelope is ragged around the surface of the egg and not smooth, as in other species.

The Nymph.—Although the imago of Leucorrhinia is much smaller than that of *Libellula luctuosa* the nymph is considerably larger, measuring 1.20 mm. in length; the head is one-third wider than the abdomen; the front legs are the same length as the body, the others proportionally longer, and all three pairs slender. Both the body and the legs are quite transparent and pale orange yellow in color, the legs and antennæ transversely banded with gray and white, the eyes darker orange yellow, the black spots very small. The sides of the head and a wide transverse band across the anterior portion of each abdomen segment are whitish, the posterior margins of the segments are tinged with brown. The bases of the antennæ are whitish yellow proximally, with a narrow, gray, distal band; first joint entirely white, a little grayish through the center; second joint with a very narrow proximal band and a wider distal band white, grayish through the center; third joint entirely gray.



Figs. 49 to 51.—Development of *Leucorrhinia intacta:* 49, egg; 50, mask of newly hatched nymph; 51, newly hatched nymph.

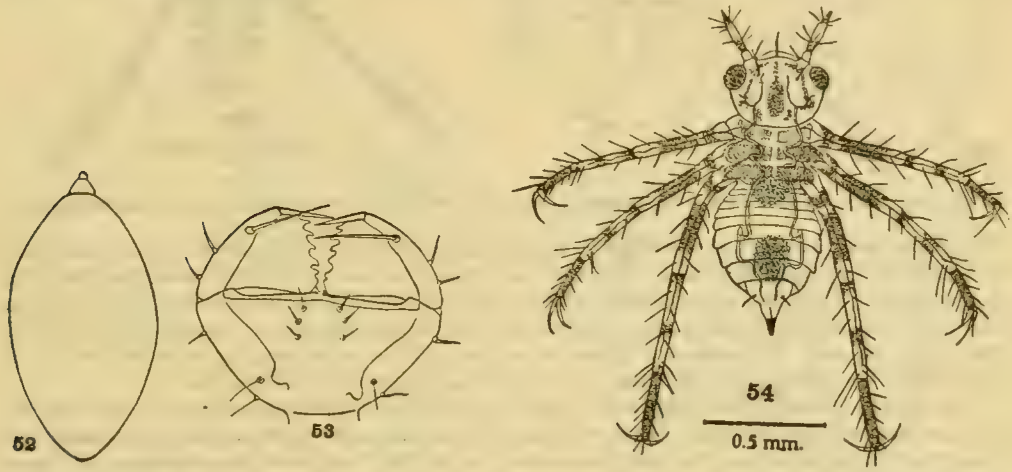
The Mask.—Mentum three times as wide as long; the distal margin twice the length of the proximal; no lateral setæ; two marginal setæ; three mental setæ on either side, not in line, but the proximal one nearest the midline; two stout spines at the center of the distal margin. Lateral lobes with length and width in the proportion of 13 to 9; two setæ on the outer margin on either side; two setæ on the blade of each lobe; raptorial seta reaching considerably beyond the tip of the movable hook, the latter long and narrow; three small teeth near the outer edge of the distal margin, the central tooth the largest, the rest of the margin smooth.

PLATHEMIS LYDIA.

The females of this species remain at some distance from the water, except at the time of ovipositing; one caught a quarter of a mile from the ponds deposited eggs freely on July 25, which began to hatch August 2, and were all hatched by August 9.

The Egg.—These eggs are elongate elliptical and rather pointed at both ends, just twice as long as wide, the two diameters being respectively 0.60 mm. and 0.30 mm. The neck is as wide at the base as it is high, with a distinct segmentation near the tip, the latter being undivided; there is no process on the posterior end of the egg.

The Nymph.—The general color of the nymph is yellowish white, with light-brown markings. On the center of the dorsal surface of the head is a longitudinal, club-shaped, brown area and on either side a broken semicircle; there is a large, irregular, brown spot in the center of the posterior thorax and anterior abdomen, and another smaller spot over the posterior end of the respiratory system. The eyes are dark brown, with black, retinal spots; the tracheal system is yellowish brown. The head is a trifle wider than long and not narrowed behind the eyes; the thorax is two-thirds as wide as the head; the abdomen the same width as the head, sharply pointed posteriorly, with strongly convex, lateral margins and no color markings except the two spots already noted. The base and basal joint of the antennæ are whitish; proximal end of second joint and the whole of the third joint light gray, distal part of second joint white. The legs are light gray and white; the tips of the posterior processes of the abdomen are dark brown; the terga of the thoracic segments are light gray.



FIGS. 52 to 54.—Development of *Plathemis lydia:* 52, egg; 53, mask of newly hatched nymph; 54, newly hatched nymph.

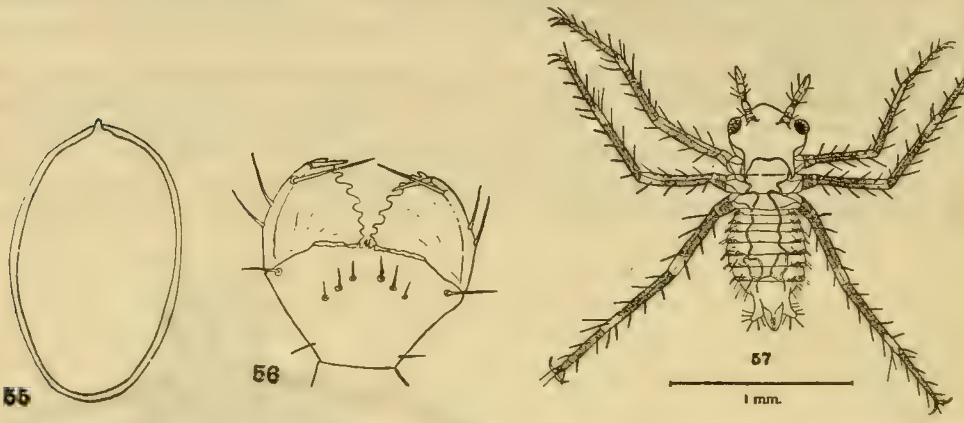
The Mask.—Mentum twice as wide as long, with convex sides; distal margin two and a half times the proximal; one lateral seta near the base on each side and two marginal setæ; three mental setæ on either side of the center in a curve concave to the midline; two small spines at the center of the distal margin. Lateral lobes one-half longer than wide; two setæ on the outer border, none on the blade; raptorial seta just reaching the tip of the movable hook, the latter short and stout; distal margin with seven teeth reaching nearly the entire width, the third tooth the longest.

EPICORDULIA PRINCEPS.

The eggs of this species are laid in long, jelly-like strings, similar to those of Tetragoneuria. Some of these strings were obtained from the leaves of *Potamogeton illinoiensis* in pond 3D on August 9, 1917; but, of course, there was no way to tell when they were laid; they began to hatch within a day or two.

The Egg.—This egg is the largest of any here described, being 0.72 mm. long and 0.40 mm. wide. The neck is a minute process of the same height and width, without segmentation, and there is no process on the posterior end of the egg.

The Nymph.—Like the egg from which it was hatched, the nymph is a little larger than any of the others here included, being 1.25 mm. long and 0.42 mm. in diameter. Its general color is white, the eyes and the center of the abdomen reddish brown, the respiratory system bright yellow. There are two comparatively large horns on the dorsal surface of the head at the posterior margin, with their tips turned back like hooks; that is, they are slightly "cultriform" (Needham). The inferior posterior appendages of the tenth abdomen segment are large and are turned over vertically at right angles to the body axis. The antennæ are banded with black and white in sharp contrast; the base with a narrow, white, distal band; the basal half of the first joint black, the distal half white; the second joint the same, the third joint entirely white. The legs are transparent, with very little differentiation in color, the tips of the basal joint, the femur, and the tibia being somewhat whiter than the rest of the joint. The thorax is pale white, without any pigment; the abdomen is brownish red through the center over the intestine, with short, dark spots on the posterior margin at the outer edge of each segment, the rest white.



FIGS. 55 to 57.—Development of *Epicordulia princeps:* 55, egg; 56, mask of newly hatched nymph; 57, newly hatched nymph.

The Mask.—Mentum three-fifths wider than long, its sides slightly concave; the distal margin a little less than twice the proximal; one lateral seta, two marginal setæ on either side; three mental setæ on each half in a straight line, the distal one nearest the midline; four stout, sharp spines at the center of the distal margin. Lateral lobes about the same length and width; two setæ on the outer border, none on the blade of the lobe; raptorial seta reaching beyond the tip of the movable hook, the latter short and stout; distal margin with 10 teeth covering its entire width, the outer 5 much larger than the inner 5 and cultriform. Lateral seta on mentum often lacking as in figure 56.

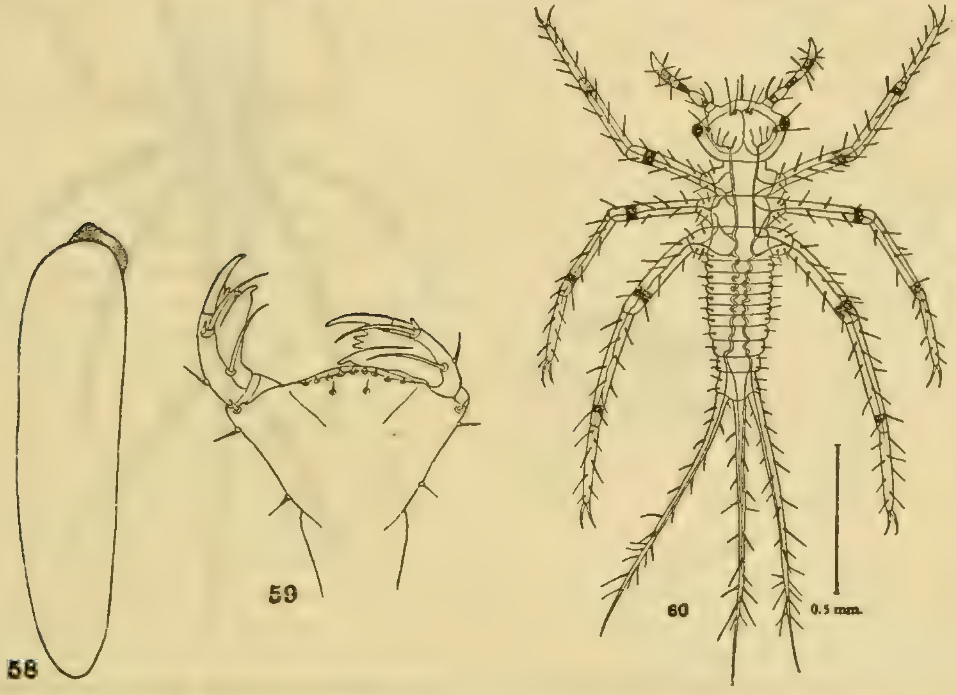
ENALLAGMA HAGENI.

The eggs were laid in the leaves of crex grass; more than a thousand were obtained from five grass leaves July 26, 1917. These began to hatch in two weeks and continued hatching for 10 days, but, like the eggs of Epicordulia, there was no way to determine just when they were laid, so that the period of incubation is uncertain.

The Egg.—These eggs were in the form of an elongated ellipsoid, the long diameter four times the shorter one, the anterior end broadly and bluntly rounded, the posterior end pointed; neck short and broad and brown in color.

The Nymph.—The head is transversely elliptical in outline, the two diameters in the ratio of 8 to 5; there is a pair of setæ just inside of each eye on the dorsal surface, another pair close to the midline, just behind the anterior margin, and a single seta at the center of the margin itself. The thorax is considerably narrower, but almost twice as long as the head; the legs are long and stout, the posterior pair reaching somewhat beyond the center of the caudal gills. The abdomen is a little wider than the thorax anteriorly and does not narrow much in front of the seventh segment. The antennæ are long and stout, with a gray band at the base of each joint; caudal gills as long as the rest of the body and cylindrical, covered with short and straight spines or setæ. All the leg joints, including the coxæ, are sparsely armed with setæ; and there is a row of setæ also along the dorsal surface of the abdomen close to the lateral margin. The color is a uniform, creamy white, except the three dark bands on the antennæ and a narrow band on each femur and tibia of the legs.

The Mask.—Mentum triangular, one-half wider than long; distal margin twice the length of the proximal; one mental seta on either side, one lateral seta at the base of each lobe, two marginal setæ; a row of nine small spines just behind the distal margin. Lateral lobes twice as long as wide, with one marginal seta and two raptorial setæ; movable hook long and stout; an accessory spine just outside the base of the distal raptorial seta.



FIGS. 58 to 60.—Development of *Enallagma hageni:* 58, egg; 59, mask of newly hatched nymph; 60, newly hatched nymph.

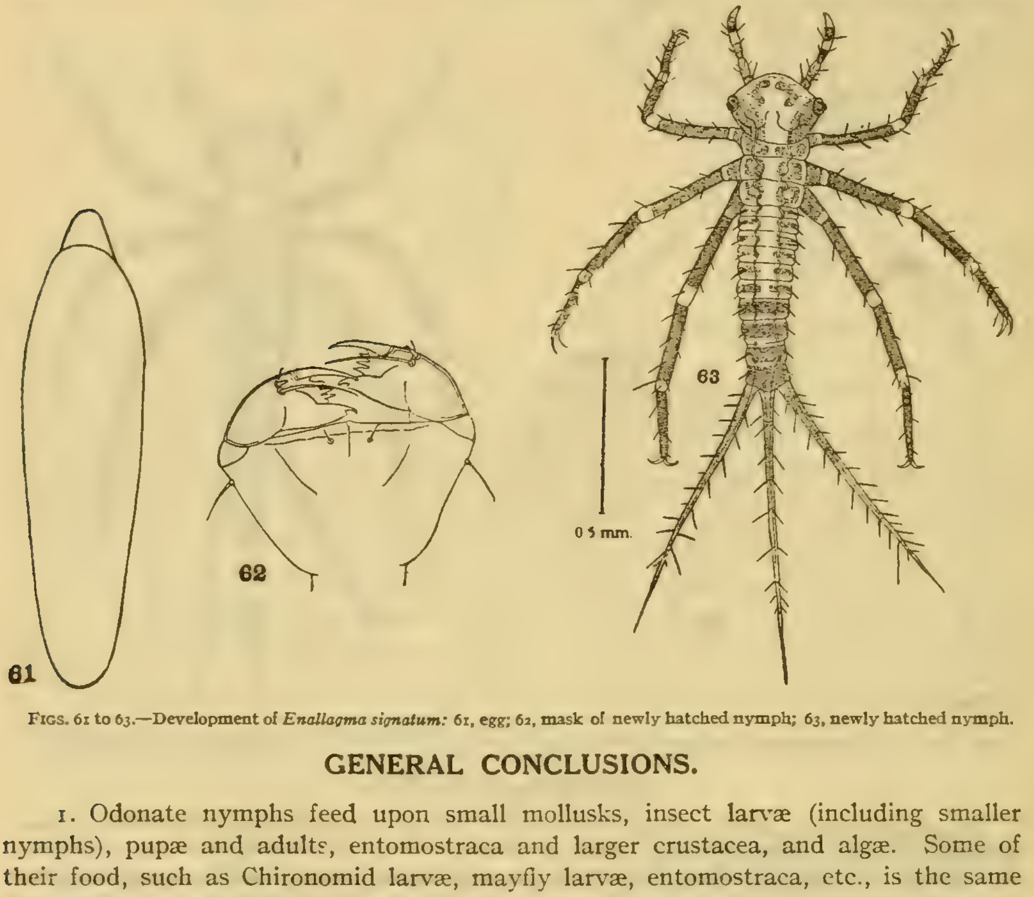
ENALLAGMA SIGNATUM.

These eggs were obtained from pond-lily leaves on July 28, 1917, and began to hatch 18 days later, the period of incubation being again unknown.

The Egg.—The eggs are considerably like those of *E. hageni*, but they were arranged very differently in the tissues of the leaf. Those of *hageni* were inserted without any definite order anywhere in the leaf; these were arranged in a semicircle on the underside of the leaf around some convenient hole or close to the margin. The female evidently thrust her abdomen down through the hole or down over the edge of the leaf and, reaching as far as she could, inserted the eggs into the leaf.

The Nymph.—The nymph is just 1 mm. long, exclusive of the caudal gills; head wider than long, the two diameters in the proportion of 7 to 5, the anterior and posterior margins both strongly convex; thorax shorter than the head and two-thirds as wide; abdomen the same width as the thorax and tapering gradually backward; caudal gills short and slender; legs also comparatively short and slender, the posterior pair not reaching the center of the caudal gills; claws short and stout. The antennæ are long and stout; the eyes at the center of the lateral margins project strongly. There are no setæ on the dorsal surface of the head, on the thorax, or on the coxæ of the legs; there is a single seta on the center of each abdominal segment near the lateral margin on each side; and the setæ on the legs and caudal gills are small and scattering. The ground color is white, covered with a complicated pattern of light russet brown; last four abdominal segments, legs, and caudal gills nearly all brown, with narrow stripes of white; respiratory tracheæ bright golden yellow.

The Mask.—Mentum one-half wider than long, with slightly convex sides; distal margin nearly three times the proximal; no lateral setæ, one marginal seta near the distal end, one mental seta; distal margin smooth. Lateral lobe three-fourths longer than wide; no setæ on the outer margin; raptorial seta just reaching the tip of the movable hook, the latter long and stout; a minute accessory spine outside the base of each raptorial seta; distal margin deeply toothed, inner tooth cultriform.



FIGS. 61 to 63.—Development of *Enallagma signatum:* 61, egg; 62, mask of newly hatched nymph; 63, newly hatched nymph.

GENERAL CONCLUSIONS.

1. Odonate nymphs feed upon small mollusks, insect larvæ (including smaller nymphs), pupæ and adults, entomostraca and larger crustacea, and algæ. Some of their food, such as Chironomid larvæ, mayfly larvæ, entomostraca, etc., is the same as that of young fish, but they also eat the larvæ or adults of many animals that are directly harmful to small fishes, such as diving beetles, water boatmen, crayfish, and Cypris.

2. A few of the largest species may sometimes eat a small fish under natural conditions, but this is apparently due to stress of hunger and the lack of other food. Warren has proved (p. 206) once for all that the diet of a nymph in captivity furnishes no criterion whatever as to its natural food. Careful observations under natural conditions show that even an Anax nymph need not be regarded as a menace to fish culture, but that it may become actually beneficial.

3. Odonate nymphs furnish one of the very best foods for fishes; the small species and the young of the larger species are freely eaten by the fingerlings of practically all

our fresh-water game and food fish, while the larger species when fully grown are just as toothsome to adult fish. The large percentage of nymphs in the food of fishes from the Fairport ponds (table, p. 228) effectively answers the objection that odonates rob the fishes of a part of their food.

4. If the Anax, Æschna, and other large nymphs are preying upon the fish in any given fishpond, this should be interpreted by the fish-culturist as evidence that the supply of food in that pond is running low. His efforts can better be directed toward replenishing the food supply than toward getting rid of the nymphs. On the other hand, if they do not disturb the young fish the food supply is adequate, and they themselves will contribute to it in due time. They thus furnish a convenient means of testing the food supply, since it is an easy matter to examine their stomachs and find out what they are eating.

5. Odonate imagos feed exclusively upon adult insects; their prey, like that of the nymphs, sometimes includes insects that are beneficial, such as other odonates, honeybees, and hymenopterous parasites; but the bulk of their food is made up of insects that are either positively injurious or negatively of no practical importance. Among these may be mentioned gall flies, tsetse flies, plant lice, leaf hoppers, ants, and all kinds of small moths and butterflies. They also confer an inestimable benefit upon mankind by waging an incessant warfare upon house flies, mosquitoes, black flies, and gnats. This one benefit alone far outweighs any harm they may do to the fish and should earn for them a cordial welcome to every fishpond, present and future.

6. Odonate imagos, like the nymphs, furnish good food for adult fishes, as is evidenced by finding them in the stomachs of various fishes taken under natural conditions and from the fishponds. It has also been demonstrated by feeding live dragonfly imagos to game fish in fishponds.

7. Both nymphs and imagos are important factors in establishing a natural equilibrium in the fauna and flora of the fishpond and its immediate environment. Other things being equal, such an equilibrium contributes materially to success in fish culture, and it can not be obtained without the presence of the nymphs and imagos. Incidentally, if properly chosen, the imagos will add greatly to the attractiveness of the fishpond and its surroundings.

8. Hence care should be taken that the pond is supplied with odonates, as well as with fish; after the original stocking they can be left to take care of themselves. For stocking purposes use common local species of dragonflies and damselflies; Anax, *L. pulchella*, Plathemis, and the damselfly genera, Argia, Enallagma, and Lestes are so cosmopolitan that they will make good stock almost anywhere in the United States. Here again the odonates constitute a sort of visible pulse of the life of the pond; so long as they remain vigorous and healthy the pond life is probably moving along smoothly.

9. Small breeding ponds along the margin of the fishpond from which the fish are excluded will materially increase the supply of all aquatic insects, including the odonates. If these are started in the spring or fall, the best odonate material to put into them will be the nymphs. If they are started in the summer, they can be stocked more intelligently by obtaining the eggs of desirable odonates and hatching them.

10. Dragonflies will not feed, nor mate, nor lay their eggs in captivity, but damselflies are more susceptible, and eggs could probably be obtained from any common species. If a female dragonfly be caught while ovipositing and held by one pair of wings, leaving

the other pair free, she will deposit her eggs freely in any convenient receptacle if the tip of her abdomen be dipped in water. Thousands of eggs can be obtained in this way in a short time and kept until they hatch, or they can be placed at once in the breeding pond. The eggs of Anax, Æschna, and the damselflies can be secured by watching the females while ovipositing and then transferring the leaves or stems containing the eggs to the breeding pond.

11. If there is any necessity for rearing the nymphs before placing them in the breeding pond, they can be fed on Paramœcium obtained by making an infusion of manure in water, or on ordinary tow, especially the small crustacea, which they will devour in large numbers. Warren carried dragonfly nymphs successfully through their entire life history by feeding them with mosquito larvæ and pupæ.

12. Whenever a fishpond is drained, the nymphs in it should be saved; they make excellent food for fish in other ponds and can be fed to them or can be used to restock the drained pond when it is filled again.

13. Dragonfly eggs hatch in 8 to 12 days; the nympn is short and thickset, the thorax and abdomen about as wide as the head, the legs long and slender, the antennæ short and fairly stout, the eyes large, with black retinal spots surrounded by rings of colored pigment. The mentum of the mask is much wider than long, with three mental setæ on either side and a varying number of lateral and marginal setæ. The lateral lobes have a terminal, movable hook, one raptorial seta, marginal setæ on the outer margin, and usually two small setæ on the blade of the lobe. The respiratory tracheæ are convoluted in the thorax and posterior abdomen and comparatively straight between the two, and are highly colored.

14. Damselfly eggs hatch in about three weeks; the nymph is long and slender, the thorax and abdomen considerably narrower than the head; the legs relatively short and slender; the antennæ stout and long; the eyes small with few retinal spots, but each surrounded by colored pigment. The mentum is somewhat wider than long, with a single mental seta on either side and one or two lateral and marginal setæ. The lateral lobes have a stout, terminal, movable hook and one raptorial seta. The respiratory tracheæ are highly colored and are convoluted in the thorax and anterior abdomen and are comparatively straight posteriorly. The caudal gills are cylindrical, very long and slender, and taper regularly from the base to the tip.

ANNOTATED LIST OF DRAGONFLIES AND DAMSELFLIES OBTAINED NEAR FAIRPORT, IOWA.

THE GENUS GOMPHUS.—The nymphs of this genus live in the mud or sand on the bottom of the Mississippi and its tributaries, and thus far none of them has been found in any of the fishponds. There is no reason, however, why pond species like *graslinellus* and *submedianus* should not be found there, as they probably will be in the future. They burrow into the mud and débris, leaving only the tip of the abdomen exposed for respiration, and lie in wait for their prey. They are both rapacious and omnivorous and will eat anything and everything small enough to be caught and held by their powerful jaws. They may be recognized by their thick and hairy, four-jointed antennæ, which are usually inclined inward toward each other, by a flat labium simply folded beneath the chin, with strong grasping arms like mandibles and not extending up over the face in a mask, and by the absence of dorsal spines along the midline of the abdomen. Their legs are stout and adapted for burrowing, the two front pairs directed forward and the posterior pair directed backward, and all three pairs armed at the tips with strong burrowing claws. Their color is similar to that of the débris in which they live, and the furry hairs covering their bodies and legs quickly gather a coating of mud which still further obscures them. When ready to transform they crawl up on some board surface like a floating barge, the side of a boat, the bark of a tree, or more commonly a flat mud surface close to the water. In suitable locations the mud will be found thickly incrusted with their nymph skins, and it is not uncommon to find two or more skins one on the top of another, those coming out last crawling up on the others.

The imagoes scatter quickly as soon as they are able to fly and often entirely disappear from the vicinity where they leave their nymph skins. In general, the females retire inland, while the males remain along the water front.

Their habits are very different from those of the Libellulidæ, the imagoes usually alighting flat on the ground or close to it, or on the surface of a log, and squatting or flattening the body down until the wings almost touch the ground, all ready to spring upon their prey. They almost never alight on twigs or grass stems, like the Libellulidæ. From this flattened position they dart out over the water, skimming close to the surface and going toward the center of the river or stream, and then return again to the bank. Their motion is more similar to the ordinary aeroplane than that of most Libellulids, and they often hover over one spot for some time. They pluck much of their prey off the surface of the water, and some species actually dive beneath the surface, entirely disappearing under the water.

Although two of the species, *externus* and *vastus*, are common about the ponds, they have never yet been observed hunting their prey over the pond surface. They do catch numbers of teneral dragonflies and damselflies, however, in the vegetation around the margins of the ponds.

The imagoes are so nearly alike in color pattern, wing venation, and even in habits, that it is very difficult for anyone but an expert to distinguish the various species, but the nymphs afford much plainer distinctive characters.

The pairing of the sexes occurs toward evening, and if one goes out just before sunset there is a good chance of obtaining the two sexes together. The male does not accompany the female while ovipositing, and the sexes never fly about together after the manner of some of the Libellulidæ.

GOMPHUS PLAGIATUS Selys.

Gomphus plagiatus Selys, Bull. Acad. Belgique, 1854, vol. 21, p. 57.

In the Proceedings of the Indiana Academy of Science for 1901, page 123, Williamson said: "The why, whence, and whither of imago Gomphi is a puzzle." And to no species of the genus apparently does it apply any more forcibly than to the present. The nymph skins of this species were by far the most abundant of any found along the river bank, and over 1,000 were collected during the summer. But the only imagoes caught or seen were two tenerals captured as they were emerging. The imagoes must depart as soon as they can fly at all, and apparently they remain in the place to which they go. Consequently this species can hardly be said to have any part at all in the ecology of the fishponds although such large numbers of them are transformed within a few hundred feet of the ponds.

Emergence takes place early in the season, usually during the night, so that by the next morning the imago can fly fairly well.

GOMPHUS VASTUS Walsh.

Gomphus vastus Walsh, Proc. Acad. Nat. Sci., Phila., 1862, p. 391.

This species was third in abundance, judging by the number of skins obtained, and it takes an active part in the odonate life around the ponds.

While the imagoes emerge along the river bank, and while many of them remain there, others migrate to the vicinity of the ponds. Most of these migrants are females, although there is a respectable sprinkling of males. And yet none of them ever deposits eggs in the ponds; they all return to the river. Hence the part which they play is strictly confined to the imagoes, and consists wholly in the consumption of various insects and the teneral imagos of smaller dragonflies.

GOMPHUS EXTERNUS Hagen.

Gomphus externus Hagen, Monogr. Gomphidæ, 1857, p. 411.

This species was second in abundance, as shown by the skins collected. The sexes seemed fairly well divided, and specimens could nearly always be seen along the cinder road to the north of the ponds or in the vegetation on the embankments. They are active and restless hunters and voracious eaters. One female was observed July 18 eating an *Argia putrida* imago and was so intent upon her meal that she allowed an approach to within 2 feet. She chewed and swallowed every scrap of the large damselfly except the wings and had no sooner finished than she caught another and ate it similarly. Such gormandizing must of necessity play an important part in the ecology of the ponds. Like *vastus*, this species returns to the river for ovipositing, and its nymphs are never found in the ponds.

Like *plagiatus*, emergence takes place during the night, and many tenerals were found early in the morning at the season of transformation, which seems to last through June and July.

GOMPHUS SUBMEDIANUS Williamson.

Gomphus submedianus Williamson, Entomol. News, 1914, vol. 25, p. 54.

This species was found only at Patterson Lake and Sunfish Lake, on the Illinois side of the Mississippi River, just above Fairport. The males were plentiful along the banks of the lakes, while the females were found in swampy places some distance back in the woods. Specimens were sent to E. B. Williamson, the founder of the species, and he very kindly confirmed their identification. The males usually fly close to the surface of the water and have the habit of hovering for a short time over one spot after the manner of some of the other Gomphids. They also frequently alight upon floating logs, bushes, or some water plant. While hovering, the seventh, eighth, and ninth abdominal segments have a decided reddish tinge when the sunlight strikes them just right.

GOMPHUS AMNICOLA Walsh.

Gomphus amnicola Walsh, Proc. Acad. Nat. Sci., Phila., 1862, p. 396.

This species was especially abundant along the banks of the river just above the ponds in series B and was occasionally captured around the fishponds. While the exuviæ collected give us the best idea of the actual number of imagoes of the various species, the apparent abundance does not always correspond. The present species was seen and captured as often as any other single species, but in the number of exuviæ it was far behind most of the other Gomphids. Evidently these imagoes do not migrate after their emergence, but stay around in the immediate vicinity.

This dragonfly frequents the thick grass and underbrush a little back from the water's edge and can be captured with comparative ease.

The nymphs and nymph skins were all obtained from the river, and none was found in any of the ponds.

GOMPHUS NOTATUS Rambur.

Gomphus notatus Rambur, Ins. Neur., 1842, p. 162.

This dragonfly is a little larger than *amnicola*, but has similar habits; it stays out in the open rather more, but is occasionally found in the thick grass. Its favorite haunt is along the river's bank, whence it makes long flights out over the water, returning again to nearly the same place. The nymphs frequent the shallower portions of the river, and none are ever found in the ponds.

NASIÆSCHNA PENTACANTHA (Rambur).

Aeschna pentacantha Rambur, Ins. Neur., 1842, p. 208.

This species is said to have a wide geographical range, but not to occur anywhere in abundance. It was found quite plentifully around Patterson Lake and the slew leading up to it from the river. Its habits are like those of other Æschnines; it patrols the banks, flying back and forth over a limited area and frequently alighting and clinging to the underside of twigs and branches, its body hanging vertically and its wings drooping. In this position it is not very difficult to catch. No old nymphs or nymph skins could be found, although careful and continued search was made for them, but newly hatched nymphs were obtained in August, 1917.

ANAX JUNIUS (Drury).

Libellula junia Drury, Illust. Exot. Entomol., vol. 1, 1773, p. 112.

According to Kellicott, this species is the first to appear in the spring and almost the last to disappear in the fall. During June the imagos were not very plentiful around the ponds, but they increased greatly in actual numbers and still more in relative abundance as the season advanced, and by the last of August they were surpassed only by *Libellula luctuosa*. This is one of the most powerful fliers and almost never alights except for ovipositing. At such times the two sexes fly about together and, alighting upon some water plant at or near the surface of the water, the male assists the female as she inserts her eggs in the tissue of the plant stem. Both sexes often have a regular beat which they patrol back and forth for a long time; they also fly later at night than any other species, sometimes high in the air, catching the numerous small insects which they find there.

Nymphs were found in all the ponds, but especially in 4 and 9, where they were not much disturbed by the fish. This nymph is probably better known and more often figured than that of any other dragonfly. It shows a great variety in its color pattern at different ages, as well as the usual differences according to the nearness of the next molt. When very small, it is a uniform greyish green; as it grows larger it becomes banded transversely with black and white, while the mature nymphs are bright grass-green, with a beautiful and intricate color pattern of cinnamon brown. Two medium-sized nymphs were taken in pond 4 that were snow white throughout and so transparent that the dark breathing tracheæ around the posterior intestine showed through plainly.

The nymphs are most abundant in waters filled with vegetation, and may be found even in small ditches and pools, and there are sometimes two broods in a year. They expel the water from their rectum with a noise like that made in ejecting saliva, and such spitting served to locate most of them in pond 4 when the water was drawn. When those that were left in this pond transformed, they seemed to find the screen across the outlet peculiarly attractive, and it was covered with bunches of skins. Two of these bunches are shown in Plate LXVIII, figure 1, the right-hand one containing six skins in a row, each fastened to the one in front of it.

ÆSCNHA CONSTRICTA Say.

Æschna constricta Say, Jour. Acad. Nat. Sci., Phila., vol. 8, 1839, p. 11.

Nymphs were found in all the ponds associated with those of Anax; they do not transform until midsummer or later, and hence no imagos are seen until then. The imagos frequently enter houses or other buildings and may often be captured there. They wander afar in the fields and are seldom seen around the ponds, preferring some small brook among the hills. They feed on flies as well as mosquitoes and often catch house flies and stable flies around our dwellings.

MACROMIA TÆNIOLATA Rambur.

Macromia tæniolata Rambur, Ins. Neur., 1842, p. 139.

This and the following species were only found in the slews along the Mississippi River. None have ever been seen around the fishponds, nor have any nymphs or nymph skins been found there. Patterson Lake is a favorite resort of the imagos, but careful search in its waters failed to reveal any nymphs.

MACROMIA ILLINOIENSIS Walsh.

Macromia illinoiensis Walsh, Proc. Acad. Nat. Sci., Phila., 1862, p. 397.

Like the preceding species this one is never found around the ponds, but may be seen frequently along the river bank and at sunset in the cornfields flying back and forth between the rows. At night both species congregate in favorite places upon low bushes and hang by their legs from the under side of the branches like Nasiæschna.

EPICORDULIA PRINCEPS (Hagen).

Epitheca princeps Hagen, Synop. Neuropt. of N. A., 1861, p. 134.

This species is easily recognized by its large size, by the brown blotches on its wings at the nodus and stigma, and by the fact that there are never any white areas connected with these blotches as in *L. pulchella.*

The males have regular areas which they patrol incessantly hour after hour, hawking the varied insect life they may find.

The nymphs are common in all the ponds; but the imagos scatter after emerging, and only a few are seen about the ponds at any one time. The nymph is large and sprawling and can not cling well to grass stems, preferring a broad surface like a board, a stump, or even the side of a bank. Most of those taken at the ponds were found on a hard mud bank beside the cinder road. The two sexes do not fasten together during oviposition, but the female drops her eggs alone into deep water.

The imago emerges early in the morning and is one of those that consequently falls a prey to the birds, since it is helpless during the first forenoon. Some of the wings of this species were found with those of *L. luctuosa* already noted (p. 222).

PANTALA FLAVESCENS (Fabricius).

Libellula flavescens Frabricius, Entomol. System. Supple., 1798, p. 285.

This species was found more plentifully upon the Illinois side of the river, but was occasionally taken around the fishponds. Nymphs were found in ponds 4 and 8, and skins were obtained along the shores of ponds 1, 2, and 3.

The imagos are rapid flyers and very difficult to capture while on the wing; they congregate in open places near the river bank, where they may be recognized by their reddish-yellow color and strong flight.

Apparently they never become really numerous anywhere in the vicinity of the station, but are one of the rarer species.

PANTALA HYMENÆA (Say).

Libellula hymenæa Say, Jour. Acad. Nat. Sci., Phila., 1839, p. 18.

Similar to *flavescens*, but with a distinct fuscous spot at the base of the posterior wings; common along the river bank just above the ponds in series B. Like *flavescens* they are rapid flyers and difficult to capture while on the wing, but, unlike that species, they frequently alight upon the under side of a twig of some bush or tree like Macromia and Nasiæschna, and can then be captured easily.

Nymphs were taken in ponds 3 and 4, but no skins were found in any of the counts made. Neither imagos nor nymphs occur in sufficient numbers to affect the ecology of the ponds.

TRAMEA LACERATA Hagen.

Tramea lacerata Hagen, Synop. Neurop. N. A., 1861, p. 145.

This species can be readily recognized even when flying by the large black blotches at the bases of the posterior wings. The male accompanies the female while ovipositing, and the two may frequently be seen flying tandem over the ponds. Early in the season, June and the first of July, the species is comparatively rare, but later they become more numerous and by the last of August they share with Anax the honors of first place. Nymphs were found in all the ponds, and skins were obtained in every count made, those in August being especially numerous.

TRAMEA ONUSTA Hagen.

Tramea onusta Hagen, Synop. Neurop. N. A., 1861, p. 144.

A single male of this species was captured on pond 8D in July, 1917, and others were seen later about several of the ponds. It can be readily distinguished from lacerata by the reddish color of the blotches at the bases of the wings. Neither nymphs nor skins were secured.

PERITHEMIS DOMITIA (Drury).

Libellula domitia Drury, Illust. Exot. Entomol., vol. 2, 1773, p. 83.

This is the smallest of the dragonflies and may be distinguished from the others here mentioned by its diminutive size and its amber-tinted wings. The imagos are as common about the ponds as elsewhere, but are not very abundant anywhere. It is a slow and clumsy flyer, approaching more nearly to the damsels than to the other dragons. Its small size gives it very little confidence and it keeps well out of the way of other species, flying close to the surface of the water.

The female is usually found in the fields some distance away from the ponds, and she deposits her eggs unattended by the male.

The nymphs are found sparingly in all the ponds and were also obtained from Patterson Lake on the river; they are cleaner, as well as smaller, than most other species. The skins are always found close to the water's edge, often over the water, apparently on the first suitable stem that the nymph met with.

CELITHEMIS EPONINA (Drury).

Libellula eponina Drury, Illust. Exot. Entomol., vol. 2, 1773, p. 86.

These dragonflies can be recognized by their heavily spotted wings and by their habit of balancing upon the very tip of some convenient grass or weed stem. When disturbed they return again to the same spot, and this makes them easy to capture. Their flight is slow, and in the position and movement of the wings bears more resemblance to that of a butterfly than of other dragonflies. They are seen paired and flying tandem more often than other species, and in spite of their slow flight they are more in evidence on windy days.

The nymphs are found in all the ponds, while the skins are found close to the water's edge, like those of Perithemis. The small size and scarcity of both species gives them but little influence in the ecology of the ponds.

CELITHEMIS ELISA (Hagen).

Diplax elisa Hagen, Synop. Neurop. N. A., 1861, p. 182.

This species was first seen around the fishponds in the summer of 1917. One or two were seen in 1918, but none was captured. A male and female were secured on July 1, 1919, near ponds 4 and 8 of series D.

LEUCORRHINIA INTACTA (Hagen).

Diplax intacta Hagen, Synop. Neurop. N. A., 1861, p. 179.

This is another small species familiarly known as "Johnny Whiteface"; it may be recognized by its diminutive size and its snow-white face combined with a dark body and clear wings. The two sexes do not fasten together during ovipositing, but spend much of their time perched separately on some convenient object near the water. They fly only short distances from one resting place to another, but forage continuously all summer long. Their nymphs are found in all the ponds and much resemble those of Celithemis and Perithemis, but are shorter and generally show a definite color pattern of dark brown on a greenish background. They are lively and clamber about on the submerged vegetation with considerable agility.

SYMPETRUM RUBICUNDULUM (Say).

Libellula rubicundula Say, Jour. Acad. Nat. Sci., Phila., 1839, p. 26.

This species appears early in the season and remains until after the frosts of October. At first the adults are very soft and seem to remain teneral a long time, but later they become firmer and by September are as rigid as any of the smaller species.

The imagos are found in large numbers around the ponds, but stick to the vegetation and do not fly out over the water. The nymphs were found in all of the ponds; and nymph skins were present in all the counts.

SYMPETRUM CORRUPTUM (Hagen).

Mesothemis corrupta Hagen, Synop. Neurop. N. A., 1861, p. 171.

Appears early in the season and is common around the ponds; then diminishes gradually and by the middle of August entirely disappears.

Nymphs were found in all the ponds, and nymph skins occurred in the first two counts. It is the largest species of the genus and the strongest flyer, going out, like other dragonflies, over the water, but never in numbers, and remaining but a short time.

ERYTHEMIS SIMPLICICOLLIS (Say).

Libellula simplicicollis Say, Jour. Acad. Nat. Sci., Phila., 1839, p. 28.

Second in abundance at the ponds, sticking close to the grass and weeds and never taking long flights. It does not perch on the sides of the grass stems like *L. luctuosa*, but prefers a horizontal blade of grass and settles down flat upon it. The females hunt almost exclusively in the grass and feed upon diptera, small butterflies and moths, and damselflies, especially teneral *Enallagmas* and *Lestes* (Pl. LXIX, fig. 2.)

Williamson (1899, p. 326) has noted a peculiar habit of the males. Two of them hover over the surface of the pond close to the water, one a few inches above and in front of the other. The lower one then rises in a curve over the back of the upper one, which at the same time moves in a curve downward, backward, and then upward, so that the positions of the two are exactly reversed. The two keep this up for several minutes and then separate; such movements may be witnessed on any clear day by watching for it.

The two sexes never fly about together, but the female oviposits alone, hovering close to the water and repeatedly dipping the tip of the abdomen beneath the surface. Both sexes alight on the floating algæ and other water plants, unlike most dragon flies.

The nymphs never crawl far from the water to transform, and many of the skins are found upon rush stems standing in the water. They showed a curious preference for *Carex stricta* and *Homalocenchrus oryzoides*, and but very few skins were found on other plants. Such a preference was probably due more to the position of the plants than to any other factor. The two sexes are shown in Plate LXIX, figure 1.

PACHYDIPLAX LONGIPENNIS (Burmeister).

Libellula longipennis Burmeister, Handb. Entomol., vol. 2, 1839, p. 850.

Not very common around the ponds, although a few can be found there all through the season. The matured, pruinose males are more in evidence than the females; both sexes have the habit of drooping the wings and elevating the abdomen when they alight. Nymphs were more abundant in ponds 2 and 3, and nymph skins more numerous in July and August.

LIBELLULA LUCTUOSA Burmeister.

Libellula luctuosa Burmeister, Handb. Entomol., vol. 2. 1839, p. 861.

This is by far the most common species at Fairport and can be recognized by the broad, black bands across the wings, with chalky white spots outside of them in the male. It is very energetic and active, but alights often upon the grass and sedges and sometimes remains at rest a long time. It does not hover after the manner of some species and does not hunt late at night, being rarely seen actively flying about after sunset. It roosts in the tall grass up in the fields, holding onto the grass stem well down out of sight, and sometimes in the vegetation alongside of the ponds. Its characteristic attitude is to grasp the stem with all six legs, the longer hind legs holding the body inclined at an angle of about 45° with the stem, as shown in Plate LXVIII, figure 2. It gets thoroughly wet with the dew during the night and does not start flying in the morning until the dew has dried off.

The two sexes do not fly about together after the manner of Anax, Tramea, and Celithemis, but the female oviposits alone, dropping her eggs loosely in the water, and not inserting them in the tissue of any water plant.

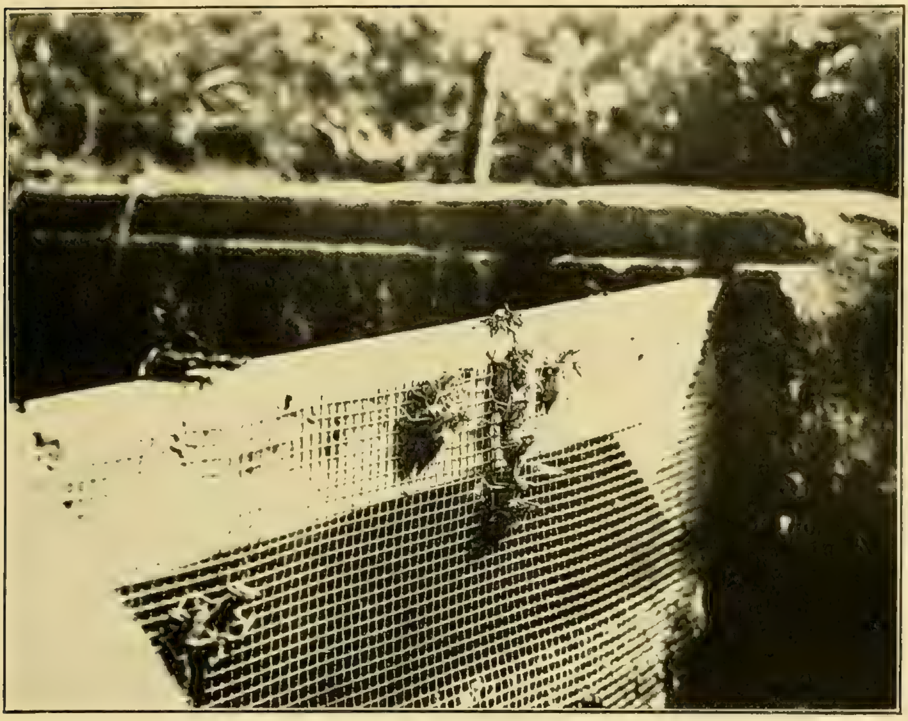


FIG. 1.—Skins of nymphs of *Anax junius* left on the screen of the outlet of pond No. 4.

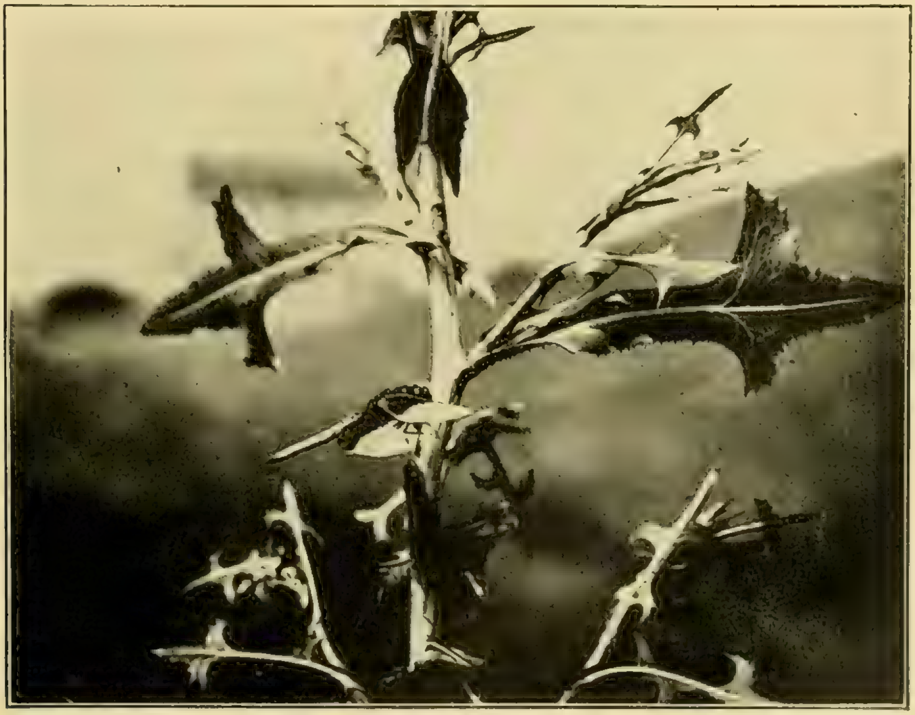


FIG. 2.—Male of *Libellula luctuosa* in characteristic attitude on the stem of a plant.

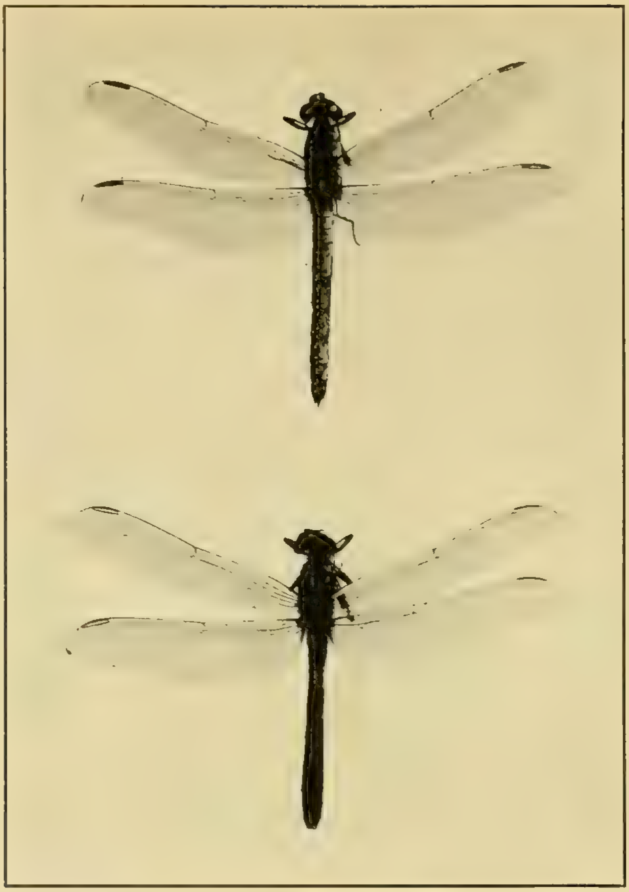


FIG. 1.—Male (upper) and female (lower) of *Erythemis simplicicollis*.

FIG. 2.— A favorite resort of *Erythemis simplicicollis* beside pond No. 2.

The males frequently come hawking around the laboratory building toward night, alight on the screens, and fly up and down the sides of the building, catching house flies, mayflies, and midges. They also have a curious habit of congregating around straw stacks in the open fields, probably attracted by the insects that frequent the sunny side of the stacks.

Over the ponds they do not keep to a definite beat or patrol, but wander about indiscriminately, the males frequently clashing with one another. So far as observed, the imagos do not eat other dragonflies or any of the larger insects. Large numbers of them while teneral fall victims to English sparrows and red-winged blackbirds.

The nymphs are found in all the ponds, but most plentifully in ponds 3, 4, and 7. These nymphs are always dirty and without a color pattern, but the dorsal hooks on the abdominal segments are always visible.

Sometimes they crawl long distances from the water, but most of the skins were found in the fringe of Carex close to the ponds. A few live in the Mississippi River, and these climb the willow trees on the bank and leave their skins attached to the bark.

LIBELLULA PULCHELLA Drury.

Libellula pulchella Drury, Illust. Exot. Entomol., vol. 1, 1773, p. 115.

Common around all the ponds, but seeming to prefer those nearest the railroad and the ditch along the railroad track. It goes much farther from the water than the preceding species and is often found along the country roads and in the farmyards, industriously hunting the insects which occur there. Nymphs were found in all the ponds, and skins were obtained in every count, but were most abundant the last of July; they are among the largest of the Libellulid nymphs and make excellent fish food.

PLATHEMIS LYDIA (Drury).

Libellula lydia Drury, Illust. Exot. Entomol., vol. 1, 1773, p. 112.

Like *pulchella*, this species prefers the ponds and the ditch along the railroad track; the nymphs were abundant in the ditch, but rare in the ponds. The male is easily recognized by his white pruinose body and black wings; the female has spotted wings and might be mistaken for *pulchella*, but is considerably smaller, and the triangle of the front wings is entirely free from color. This species is a persistent hunter, and the males have regular beats which they patrol almost constantly.

DAMSELFLIES.—The habits of the various damselflies in ovipositing and the habits and relations of the nymphs to the fish life in the ponds are so similar that a general statement will cover them all, with the exception of a few peculiarities, which may be noted under the separate species.

When ovipositing, the male grasps the female by the prothorax and flies about with her. She does not dip her abdomen beneath the surface and wash off the eggs after the manner of some dragonflies, but alights on some convenient water plant, floating algæ, pond-lily leaf, or rush stem, or upon a floating twig or piece of wood, and places her eggs in position beneath the water, the male retaining his hold and assisting her out after she has finished. Often the male holds his body erect in the air, and floating objects are sometimes covered with the females busily ovipositing, while the males stand up from the surface like small twigs or moss stems. In some genera like Lestes, Argia, and Enallagma the female descends into the water and often draws the male in with her. The females of *Argia putrida* sometimes descend 9 inches beneath the surface, the female clinging to some water plant, the male holding his body erect, with the wings spread. After placing her eggs, the female releases her hold and the two rise to the surface, their buoyancy lifting the male into the air until his wings are free. He immediately begins to fly and lifts the female out of the water, and the two then go to another place and repeat the process.

However they may be laid, the eggs hatch quickly, and the ponds are swarming during the summer time with nymphs of all sizes and kinds. These nymphs have long masks which fold back beneath the head and thorax, like those of the dragonfly nymphs. But in place of the rectal respiratory apparatus of the latter, they carry three external tracheal gills at the posterior end of the abdomen. These are flattened laterally and are usually about half the length of the abdomen, their size and shape furnishing one means of identifying the species.

Their food is similar to that of the dragon nymphs, but contains a larger percentage of small animals, as would be expected (table, p. 201). One such nymph was seen by Williamson (1899, p. 234) clinging to a dead catfish and evidently feeding on its flesh.

ARGIA APICALIS (Say).

Agrion apicalis Say, Jour. Acad. Nat. Sci., Phila., 1839, p. 40.

The male imagos of this species never become pruinose like *putrida;* one was secured from pond 5, in which the blue of segment 8 was W-shaped and restricted to the base of the segment, like that in *translata.*

The imagos were observed by Needham (1903, p. 242) at Galesburg, Ill., "feeding voraciously on adult Chironomids." The nymphs were not found at all in the ponds, but were fairly common in the river. They do not travel far when ready for transformation, but the skins are always found within a few inches of the water's edge.

ARGIA MŒSTA PUTRIDA (Hagen).

Agrion putridum Hagen, Synop. Neurop. N. A., 1861, p. 96.

The largest species of the genus; does not breed commonly in the ponds, but is very plentiful along the river. The imagos eat large numbers of mayflies, and when the latter are emerging almost every Argia, male and female, may be found munching one. The males quickly become pruinose, fading into a uniform bluish gray, but the colors are usually restored on immersion in alcohol.

The nymphs are numerous in the river, but only one or two were found in the ponds, and but few imagos were seen around the ponds. When ready for transformation the nymphs often go long distances from the water and even climb rough-barked trees. Ten skins were taken from the trunk of a large willow tree 60 feet from the water, and with them were found half a dozen skins of *Libellula luctuosa.*

AGRION (CALOPTERYX) MACULATUM (Beauvois).

Agrion maculata Beauvois, Ins. Afr. Amer., 1805, p. 85.

This beautiful damselfly is restricted to shady running water and is found only along a small brook one-fourth of a mile above the station. It sticks close to its haunts, although a male was seen one day fluttering along the shores of the ponds. Such visits, however, are only accidental, and the species does not enter into the life of the ponds to any appreciable degree.

THE GENUS ENALLAGMA.—Enallagma and Ischnura females, after inserting 8 or 10 eggs into the tissue of some plant, have a habit of stopping and straightening out the abdomen and stretching it, much as one stretches his fingers after prolonged writing. Evidently it requires considerable effort to thrust the ovipositor into the plant tissue, and since the abdomen is curved during the process it relieves the strain to straighten and stretch it.

Two Enallagma females were observed on July 26 depositing their eggs. During the process each came in contact with a partially drowned damselfly floating in the water and tossed about by the waves, which they seized, pulled out of the water and ate.

Here in the fishponds the Enallagma females seem to prefer the leaves of the crex grass as tissue in which to deposit their eggs. When the leaves break and fall over into the water, the part distal to the break dies and becomes apparently of just the right consistency to suit these damselflies, and nearly every such leaf contains eggs.

A pair of *Enallagma civile* was observed upon a bullrush stem in pond 1 D July 20, 1917. The female backed down the stem into the water for the purpose of laying her eggs. When the water reached the male and he became half submerged, he released his hold and perched on the stem above the water. But the female continued backing down the stem until she was at least 6 inches beneath the surface. Here she remained for ten and a half minutes actively ovipositing. Then a small sunfish, *Lepomis euryorus*, caught sight of her and snapped her up instantly.

The female Enallagma often gets stranded on the surface of the water with her wings wet and unable to fly. When he catches sight of her in such a predicament, a male will fasten to her and try to pull her out. Such a rescue was witnessed in pond 2D; four different males fastened to this female, but the adhesion of the water was too strong for them. They could merely tow her along on the surface, each in turn giving way when he became exhausted. But together they pulled her far enough to reach some floating algæ, onto which she crawled. Such chivalry deserved a far better reward than it received; a small cricket frog seized and swallowed her while she was drying her wings.

ENALLAGMA ANTENNATUM (Say).

Agrion antennata Say, Jour. Acad. Nat. Sci., Phila., 1839, p. 39.

This species is rare about the ponds, and only a few specimens were secured; elsewhere it is often found in large numbers and becomes the dominant species, as noted by Williamson (1899, p. 275).

ENALLAGMA CALVERTI Morse.

Enallagma calverti Morse, Psyche, 1895, p. 208.

Only a single pair was secured from pond 4, the male of which could be recognized by the excellent figures given by Williamson (1900, pl. 1).

ENALLAGMA CIVILE (Hagen).

Agrion civile Hagen, Synop. Neurop. N. A., 1861, p. 88.

This is one of the two most common species of the genus about the ponds, and its nymphs are found in every pond. In 1915 this species and *Ischnura verticalis* constituted the bulk of the damsel fauna of the ponds, but in 1916 there were fully as many of the species *hageni* as of *civile*.

Williamson stated (1899, p. 270) that old individuals of *civile* often have the wings milky or gray and the pterostigma bluish or pruinose, and this was noted in several specimens collected in September, 1915. Both the imagos and the nymphs take an active part in the life of the ponds, serving as food for fish and dragonflies.

ENALLAGMA EBRIUM (Hagen).

Agrion ebrium Hagen, Synop. Neurop. N. A., 1861, p. 89.

Moderately abundant around the ponds and found in company with other species of the genus, which it very much resembles in habits and appearance. The nymphs were more abundant than the imagos and were found especially in ponds 1, 2, 3, and 4. They are just the right size to furnish good food for young fishes.

ENALLAGMA GEMINATUM Kellicott.

Enallagma geminatum Kellicott, Etom. News, vol. 6, 1895, p. 239.

This is the smallest and most slender of the genus that frequents the ponds, but is also the most active, flying about restlessly over the water, often a long distance from the shore. It has the habit of sticking close to the surface of the water and alighting only on floating algæ, which renders it difficult to capture.

ENALLAGMA HAGENI (Walsh).

Agrion hageni Walsh, Proc. Entomol. Soc., Phila., vol. 2, 1863, p. 234.

This species, with *civile* and *Ischnura verticalis*, makes up 90 per cent of the damselfly life in and around the ponds. They are found everywhere in the vegetation near the ponds and often wander long distances into the fields and woods. They are quiet and remain well concealed, so that often when none can be seen a sweep of the net through the vegetation will reveal them.

ENALLAGMA SIGNATUM (Hagen).

Agrion signatum Hagen, Snyop. Neurop. N. A., 1861, p. 84.

This is the only orange-colored species of the genus found about the ponds, and this makes it conspicuous while flying, as well as at rest. The males and the two sexes when paired frequent the lily pads and similar water vegetation, sometimes long distances from shore. It is nearly as active and restless as *geminatum* and, like the latter, flies close to the water, making it difficult to catch. The species is common along the slews of the river as well as around the ponds and probably plays an important part in the life of those localities.

HETÆRINA AMERICANA (Fabricius).

Agrion americana Fabricius, Ent. Syst. Suppl., 1798, p. 287.

This species frequents the neighborhood of flowing water, and hence is never found around the quiet ponds, but only on the river where the current runs swiftly. It is not very common anywhere near Fairport.

ISCHNURA VERTICALIS (Say).

Agrion verticalis Say, Jour. Acad. Nat. Sci., Phila., 1839, p. 37.

This is the most common damselfly around the ponds, appearing first in the spring and disappearing last in the fall. It frequents the thick grass and other vegetation to quite a distance from the margins of the ponds. The females are dimorphic; that is, of two different colors, and the black and the orange are about equally numerous. Both sexes are weak fliers and can be caught easily in the hands. The nymphs are abundant in all the ponds, and the stem of nearly every water plant projecting above the surface is covered with their skins. The species can be raised with little trouble if suitable aquaria are provided with the stems of rushes or similar water plants projecting above the surface. As the tables show, the nymphs are eaten not only by the fish but also by the larger dragonfly nymphs. There are probably a number of overlapping broods every season.

LESTES EURINUS Say.

Lestes eurinus Say, Jour. Acad. Nat. Sci., Phila., 1839, p. 36.

This is a large and stout species and has been found thus far only at the eastern end of the ponds; its nymphs have been taken in ponds 4 and 8, but not elsewhere. The imagos are associated with those of *rectangularis* and *unguiculatus*, and late in the afternoon the three species can sometimes be obtained in one sweep of the net. In spite of its size this species is a weak flier, but is an omnivorous eater. Two females were captured with partly eaten, brown moths in their mandibles; others were found eating butterflies, small caterpillars, and even teneral Enallagmas and Ischnuras.

LESTES RECTANGULARIS Say.

Lestes rectangularis Say, Jour. Acad. Nat. Sci., Phila., 1839, p. 34.

This is a very long and slender species and may be recognized by these characters. It is the most common species around the ponds and was taken also along the river and at both Sunfish Lake and Patterson Lake on the Illinois side. It is rather more of a woodland species, but is found as well in the open, especially where there is rank vegetation to furnish shelter. It is not as omnivorous as the preceding species, but feeds largely on gnats and midges.

LESTES UNGUICULATUS Hagen.

Lestes unguiculatus Hagen, Synop. Neurop. N. A., 1861, p. 70.

The smallest of the Lestes species and found along only the eastern end of pond 4, where it is fairly common. No nymph that could be identified with this species was found in any of the ponds, although it is probable that the imagos referred to deposit their eggs in the ponds.

LESTES UNCATUS Kirby.

Lestes uncatus Kirby, Synonymic Cat., 1890, p. 160.

A single male of this species was captured in one of the runs that stretch back onto the prairie August 10, 1917. The species can not be at all common in this vicinity, since this is the only specimen secured during four years of collecting.

ISCHNURA (NEHALENNIA) POSITA (Hagen).

Agrion positum Hagen, Synop. Neurop. N. A., 1861, p. 77.

Needham (1903, p. 260) places this species in the genus Ischnura "chiefly because of the form of the abdominal appendages in the male and the small round postocular spots." Like *verticalis*, it appears early in the spring and continues until late in the fall, and its nymphs are associated with those of *verticalis* in the ponds. In habits and in their relation to the fish life of the ponds the two species may be treated as one.

NEHALENNIA IRENE (Hagen).

Agrion irene Hagen, Synop. Neurop. N. A., 1861, p. 74.

This tiny species is associated with Lestes, frequenting the grass and vegetation in damp places. Like Ischnura, it feeds upon gnats and midges. Neither the imagos nor the nymphs occur in sufficient numbers to affect the life of the ponds.

AMPHIAGRION SAUCIUM (Burmeister).

Agrion saucium Burmeister, Handb. Entomol., vol. II, 1839, p. 819.

A male and two females of this species were captured around the ponds below the railroad track July 26, 1917; none had ever been seen near the ponds in series D. However, this species is sometimes found in great numbers, and it may be that once obtaining a start here they will increase sufficiently to rank alongside the Enallagma species.

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BURROWING MAYFLIES OF OUR LARGER LAKES AND STREAMS

❧

By James G. Needham
Professor of Limnology, Cornell University

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⁂

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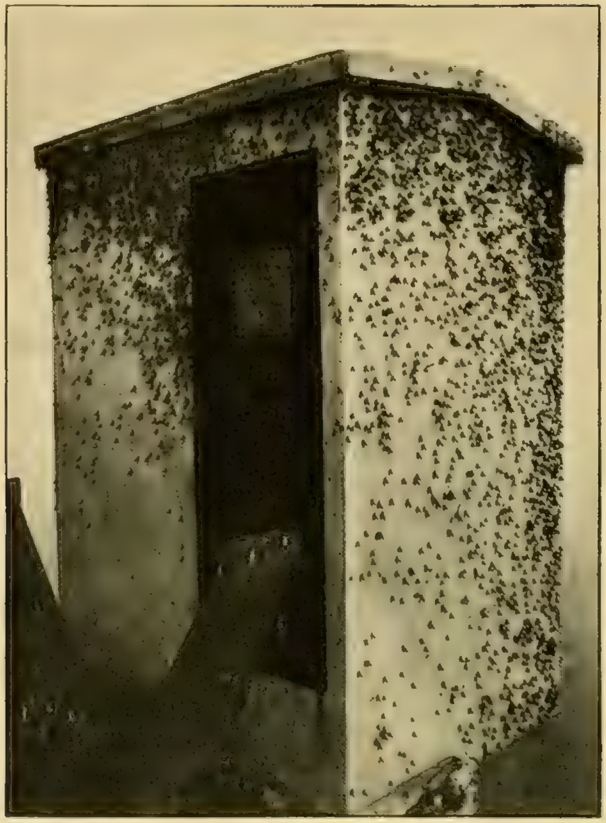

FIG. 1.

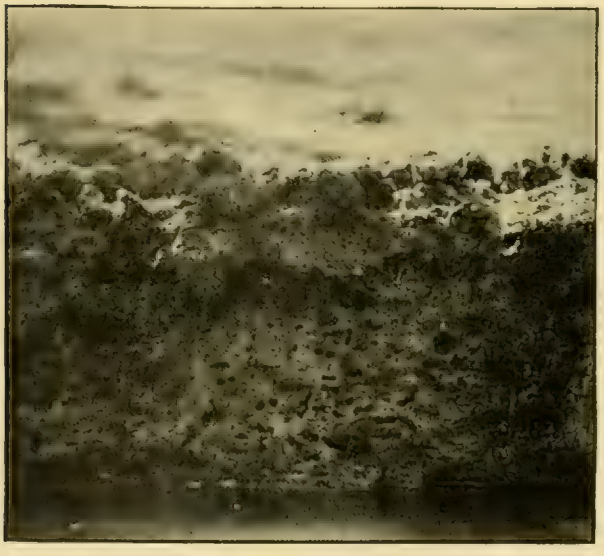

FIG. 2.

BURROWING MAYFLIES OF OUR LARGER LAKES AND STREAMS.

⁂

By James G. Needham,
Professor of Limnology, Cornell University.

⁂

INTRODUCTION.

In the beds of all our larger lakes and streams there exists a vast animal population, dependent, directly or indirectly, upon the rich organic food substances that are bestowed by gravity upon the bottom. Many fishes wander about over the bottom foraging. Many mollusks, heavily armored and slow, go pushing their way and leaving trails through the bottom sand and sediment. And many smaller animals burrow, some by digging their way like moles, as do the young of mayflies and of gomphine dragonflies; some by "worming" their way through the soil, as do the larvæ of crane flies and many oligochætes.

Among the burrowers none are more abundant or more important than the young of the mayflies. Indeed, there are hardly any aquatic organisms of greater economic value, for they are among the principal herbivores of the waters, and they are all choice food for fishes.

How abundant they are in all our large lakes and streams is well attested by the vast hordes of adults that appear in the air at the times of their annual swarming. They issue from the water mainly at night. They fly away to the banks and settle upon the shore vegetation. They cover the sides of buildings. They fly heedlessly into the faces of pedestrians. They settle upon the stream-side willows until their accumulated weight bends, and often breaks, the boughs. In the streets of riparian cities they fly to lights at night and fall beneath them in heaps upon the ground. Their bodies, crushed under the wheels of cars, render the rails slippery, sometimes impeding traffic. They feed a host of carnivores, terrestrial, aerial, and aquatic; indeed, many birds and fishes gormandize rather shockingly during their swarming season. And when those that have escaped both foes and casualties have conveyed their eggs back into their native waters, their bodies fall at last upon the surface and drift about. After the surfeited fishes can eat no more, the mayflies are blown into windrows upon the shores; or they drift in long lines that trail at the edges of the current in streams; or they gather in great masses and welter in the eddies. Sometimes they stop the river steamers by clogging the machinery. No dweller by the shores needs to be convinced of their abundance.

That they abound also far out from the shore is well attested by certain observations made by Commissioner Smith on Lake Erie nine years ago and later communicated in a letter. Dr. Smith wrote that, while making a cruise on a lighthouse tender which was visiting gas buoys in all parts of the lake, "Many of these buoys, especially those toward the middle of the lake, had enormous quantities of dead mayflies on their flat surfaces. In several cases the mayflies formed a solid cake 6 or 8 inches deep, the result of one season's accumulation."

That they are also of prime importance as food for fishes has long been known. The anglers found it out first and used the soft bodies of the larger mayflies successfully for bait. Indeed, in view of the lack of acquaintance with our mayfly species existing at the present day, the many common names for them that were used by fishermen of old seems surprising. Such old-time books for anglers as Ronald's Fly-Fisher's Entomology (1877) abundantly attest this.

Food studies have everywhere demonstrated how generally the nymphs of these big, burrowing mayflies are eaten by fishes. Forbes's report (1888*b*) was one of the most extensive. He found that these larvæ constitute nearly one-tenth of all the food taken by the fishes that he studied. He says (pp. 484-485.):

> From the order Neuroptera fishes draw a larger part of their food than from any other single group. In fact nearly a fifth of the entire amount of food consumed by all the adult fishes examined by me consisted of aquatic larvæ of this order, the greater part of them larvæ of dayflies (Ephemeridæ), principally of the genus Hexagenia. These neuropterous larvæ were eaten especially by the miller's thumb, the sheepshead, the white and striped bass, the common perch, 13 species of the darters, both the black bass, 7 of the sunfishes, the rock bass and the croppies, the pirate perch, the brook silversides, the sticklebacks, the mud minnow, the top minnows, the gizzard shad, the toothed herring, 12 species each of the true minnow family and of the suckers and buffalo, 5 catfishes, the dogfish, and the shovelfish—70 species out of the 87 which I have studied.
>
> Among the above I found them the most important food of the white bass, the toothed herring, the shovelfish (51 per cent), and the croppies; while they made a fourth or more of the alimentary contents of the sheepshead (46 per cent), the darters, the pirate perch, the common sunfishes (Lepomis and Chænobryttus), the rock bass, the little pickerel, and the common sucker (36 per cent). * * *
>
> The larvæ of Hexagenia, one of the commonest of the "river flies," was by far the most important insect of this group, this alone amounting to about half of all the Neuroptera eaten. They made nearly one-half of the food of the shovelfish, more than one-tenth that of the sunfishes, and the principal food resource of half-grown sheepshead; but were rarely taken by the sucker family, and made only 5 per cent of the food of the catfish group.

Forbes's studies were made on such material as happened to be at hand, without regard to times or seasons or conditions under which the fishes he studied had obtained their food. Subsequent studies of the food of the shovel-nosed sturgeon have made it necessary to qualify his statement as regards that fish. Wagner (1908, p. 28) says:

> The food of Polyodon consists, in Lake Pepin, entirely of plankton material, in largest part of entomostraca, but not unmixed with algæ. There is one seeming, but only seeming, exception to this. Occasionally one finds the specimens of a morning's catch largely gorged with larvæ of Ephemerids. But in every such case it was found that ephemerid imagines appeared in vast numbers the same evening. It appears plain, therefore, that the larvæ taken by Polyodon were captured on their journey to the surface of the water.

Wagner (1908, p. 31) adds concerning the valuable rock sturgeon: "The food of this fish in Lake Pepin, in the summer at least, consists entirely of the larvæ of the Ephemerids;" but he does not specify what sort of mayflies.

Pearse (1915) records that 7 of the 16 species of small shore fishes studied by him at Madison, Wis., had eaten mayflies, the percentages of this sort of food averaging as high as 58.3 per cent in the largemouth black bass and 40 per cent in the bluegill sunfish. In regularity of consumption and in amount consumed the young of mayflies were second only to midge larvæ. But Pearse also fails to specify the kinds of mayflies eaten, which omission, in view of the very great diversity in size, form, and habits of different mayflies, detracts much from the value of his report.

Materials for the present paper have been accumulated in the course of recent work done by various representatives of the Bureau of Fisheries in the Mississippi River. The most important part consists of field notes and specimens collected by Emerson Stringham in the vicinity of the big dam at Keokuk, Iowa. This includes material for the life history of a species of Pentagenia, a genus whose immature stages have not hitherto been made known. An extensive collection of aquatic-insect larvæ made by Dr. A. D. Howard in the course of a mussel-bed examination in Andalusia Chute, just above Fairport, Iowa, contains a considerable series of mayfly nymphs, mostly belonging to the group here treated. H. E. Schradieck collected adult mayflies on the grounds of the biological station at Fairport, Iowa, during the summer of 1916 and sent them to me. These adults are of the same species as are the immature stages from the mussel beds; thus they furnish additional evidence as to the mayfly population of the river. A. F. Shira, director of the station, sent me also the mayfly material from nine stomachs of the river herring (*Pomolobus chrysochloris*) collected by various persons. To this I have added data of my own, gathered during residence upon the shores of Lakes Michigan and Ontario and elsewhere.

MISSISSIPPI RIVER COLLECTIONS.

Since the pioneer work of Benjamin D. Walsh (1862, 1863, 1864) at Rock Island, Ill., the mayflies of the Mississippi have received little attention. Garman (1890) published a few observations on the habits of the adult and on the food[a] of the nymph of *Hexagenia bilineata* in the backwaters of the Mississippi bottom lands.

But it has remained for the collections above mentioned, made by Emerson Stringham, H. E. Schradieck, and Dr. A. D. Howard, to add material data. Mr. Stringham's collections, made by the waterside and along the Keokuk Dam, include adults, subimagos, and nymphs taken at transformation. Mr. Schradieck's collections, made from the walls of the biological laboratory at Fairport, Iowa, consist of adults that have flown from the river and alighted on the building. Dr. Howard's collections, made with a dredge from the bed of the river in Andalusia Chute just above Fairport, are all nymphs. These three collections supplement each other remarkably well and give a better picture of the mayfly life of the river than we have had hitherto.

Mr. Stringham's collections were made between the middle of June and the middle half of September, 1916 (save for a few adults of an undetermined species of Heptagenia taken on May 29 and a single nymph of Siplonurus taken on June 7, and neither again recorded). They relate mainly to two species: *Hexagenia bilineata* Say (Pl. LXXI) and *Pentagenia quadripunctata* Walsh (Pl. LXXIII, fig. 15). Mr. Stringham's notes were accompanied by specimens adequate for determination of the species. His record of the occurrence of these two species about the big dam is as follows:

HEXAGENIA BILINEATA.

JUNE 7.—One grown nymph collected.

JULY 12.—Yesterday I observed that a large, grayish-brown mayfly with two caudal setæ was very abundant about the dam. Still more abundant to-day.

---

[a] "The food consists of earth richly charged with dead organic matter and with unicellular plants and animals. Such protozoans as Euglena are quite common in it. A large part of the contents of the digestive tube is sand, which seems to be taken incidentally" (loc. cit., p. 180).

JULY 13.—The species collected yesterday is much more abundant to-day. They swarmed all over me while I was on the dam. Every shaded place was covered with them.

JULY 14.—Took photographs [see Pl. LXX, fig. 1] at about 5.30 a. m. of the gauge house on the dam between gates 29 and 30, covered with mayflies of which I collected specimens yesterday. In the lake above the dam there is a mass of cast skins, irregularly distributed, though the adults are distributed along the dam very generally. Have not seen this species mating.

From Keokuk to Montrose, Iowa, along the railroad track, the air was full of mayflies, all apparently the same species. The same conditions reported from Fort Madison.

JULY 15, 6.30 a. m.—Only a few mayflies on the dam to-day—comparatively few.

JULY 17.—Mr. Howland (assistant general manager, Mississippi River Power Co.) tells me that he saw a pile of mayflies in Nauvoo, Ill., this morning that was about 6 feet in diameter and 18 to 20 inches deep. When I crossed the dam to-night at about 6.45 p. m. they were quite thick and were coupling and mating while flying. Above the chutes of the lock there is an enormous floating mass consisting mainly of mixed ephemerid adults, cast skins, and duckweed.

JULY 18, 5.30 a. m.—As abundant as ever on the dam to-day. A little later.—They are more abundant than ever this morning.

JULY 22.—Still a scattering of these on the dam this morning.

JULY 26.—Still a couple of thousand on the dam. Many on train arriving from the north; so it is evident they are still coming out on the lake.

JULY 28.—Crossed the dam early this morning and was surprised to find thousands, perhaps millions, of the mayflies in the air. I believe that these are nearly as common as ever. The north end of the power house (see Bureau of Fisheries Doc. No. 805, Pl. III) is blackened with them. Workman tells me this lot has been here about two days. Night Lock Master Raber tells me the present lot started last night. Collected some in process of transformation and some apparently just ready to transform.

JULY 30.—Large mass of dead adults above the locks; smell offensive on the lee side. Very few on dam this evening (6.15 p. m.), less than a hundred, I think.

AUGUST 1 AND 2.—A few, scattering, on the dam.

AUGUST 5.—None on the dam to-day.

AUGUST 8, 11 a. m.—A scattering of large, brown ones on the dam this morning—quite a number, in fact, for the late forenoon. The shady side of the poles had a dozen or two each; some posts had more.

AUGUST 10.—A good many, but no great masses like those of last month. Collected a few at Fort Madison to-day.

AUGUST 12.—Collected some in Burlington, Iowa.

AUGUST 14.—As many on the dam as on the 10th; possibly more.

AUGUST 15 AND 16.—Mayflies still on the dam.

AUGUST 18.—Only a few dozen about the dam this morning.

AUGUST 19.—A hundred or more mayflies on the dam.

AUGUST 21.—Noticed only one live mayfly.

AUGUST 23.—Again abundant on dam. Many on the gauge house; some on power-house walls; the horizontal portions of the dam thick with them, so that at each step one or more are crushed. Heretofore they have been mostly confined to upright surfaces. Not very active; few on the wing, doubtless because of cold.

AUGUST 27.—Did not see any mayflies when crossing the dam yesterday or early this morning.

AUGUST 29.—Have not seen any more living ones.

SEPTEMBER 2.—Some of the trolley poles on the dam, of which there are about 40, had 200 or 300 of large, brown mayflies; nearly all of them had some; few compared with earlier flights.

SEPTEMBER 15, 8 a. m.—Noticed about two dozen clinging to floor of dam.

[Observations discontinued.]

Thus Mr. Stringham's records show that during the summer of 1916, at least, July was the month of the principal flights of this species; that emergence was in waves; that successive waves reached their height at about the 13th, 18th, and 23d of the month, with falling away in numbers on intervening dates; that subsequent smaller waves culminated on the 10th and the 23d of August, separated by intervals of entire absence of adults; and that belated reappearances occurred on the 2d and 15th of September. It is not likely that the first great wave arose on the 12th of July with such suddenness as Mr. Stringham's notes indicate; it is more likely that a few adults appeared earlier but were unnoticed.

Mr. Stringham noted the difference in behavior of the adult mayflies accompanying changes of temperature, adults when it is warm being able to cling to vertical surfaces, when it is cool (as on Aug. 23, minimum temperature 58° F., mean 70° F., some 15° lower than during preceding waves of emergence) lying flat upon horizontal surfaces only. That the adults adjust themselves, also, in relation to light (Krecker, 1915) and to wind is well known. Desiring to know whether waves of emergence are influenced by local meteorological conditions, I requested data from Fred Z. Gosewisch, in charge of the Keokuk station of the U. S. Weather Bureau. He very courteously sent me rather full data sheets covering temperature, precipitation, sunshine, winds, etc., and I have studied these carefully in relation to the facts furnished by Mr. Stringham, but I have not been able to trace any relation between emergence and meteorological conditions other than that which goes with the progress of the season. The mean daily temperature at Keokuk for the month of June is 72.5° F.; for July, 77° F.; for August, 74.6° F.; for September, 66.4° F. Emergence mainly occurs at the hottest part of the season, but belated transformations trail along into the comparatively cool weather of early autumn.

PENTAGENIA QUADRIPUNCTATA.[a]

JUNE 25.—They are transforming among the timbers of the boom above the lock. At 7.30 p. m. saw one leave cast (skin), and I took the insect and the cast. Took another just before it left the cast, but it struggled nearly free in the formaldehyde.[b] Saw more of these this evening than I have heretofore seen this year.

JUNE 27.—These are becoming more common. On a window sill over the water outside the compressor room, eastward of the lock, within an area of 1½ square meters, I counted 31 of them at 6.15 a. m. Other windows similarly covered. At 9.30 a. m., on the entrance door of the power house (area about 3 square meters), there were 53 of them. They were much thicker on this black iron door than on the dirty white concrete all about.

JUNE 29.—Less abundant.

JULY 1.—To-night large numbers about the power house; also about the dam.

JULY 4.—On door of power house and on adjoining walls.

JULY 11.—[No notes, but there is a vial containing a single nymph.]

AUGUST 12.—In Burlington, Iowa, yesterday and to-day, large, yellow mayflies; not very abundant.

AUGUST 23.—Scattering on dam and on power house.

AUGUST 31.—Collected a solitary live one at 7 p. m.

SEPTEMBER 2.—A few present.

SEPTEMBER 7.—One on Fisheries launch *No. 27* (ran from Fairport to Fort Madison, Iowa). Did not see any live ones about Keokuk yesterday or to-day.

These less continuous observations on Pentagenia seem to show that it appears commonly about a fortnight earlier in the season than Hexagenia, and in smaller swarms, and that it continues to appear in dwindling numbers through the season. On July 4, Mr. Stringham wrote:

> Entrance door to power house had about 200 mayflies on it this morning. The adjoining walls were likewise covered. There appeared to be seven or eight different species, but the most common

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[a] Again from Mr. Stringham's field notes.

[b] This specimen served for certain determination of the nymph, and for the life history which appears on a subsequent page.

was a small one having brownish-gray wings, light-brown body, reddish antennæ, and only two caudal setæ.

Accompanying this is a vial of the same date containing specimens of *Pentagenia quadripunctata*, *Potamanthus flaveola*, and *Chirotenetes siccus*. The commonest form was the subimago of the last named. This note has been quoted in full to call the attention of collectors to the diversity of appearance that may be presented by the different forms of a single species. Males and females differ strikingly in size of eyes, in length of legs and of tails, and in size and color; and each sex when adult may differ strikingly from its own antecedent subimago stage—the first winged stage that is assumed on leaving the water. These differences are shown side by side for *Chirotenetes siccus* in Plate LXXXII.

A single entry from Mr. Stringham's notes (August 6), the only one applying to *Polymitarcys albus* Say, is quoted subsequently under the account of that species, page 286.

Henry E. Schradieck, while engaged in other work at the Fairport biological laboratory, at my request collected from the outside of the walls of the building, as he had opportunity, samples of the winged mayflies that settled there and kindly sent them to me in alcohol. The building is some 500 feet from the river and much nearer to the fish-ponds of the station, and these collections include a mixture of forms from both of these sources. Doubtless, Bætis, Callibætis, and Cænis came from the ponds, or from slack-water shoals, rather than from the open river. The other river species in the order of their abundance were: *Chirotenetes siccus*, best flyer of them all, July; *Hexagenia bilineata*, July to October; *Polymitarcys albus*, September 6 to 11; *Pentagenia vittigera*, August 25; and *Heptagenia* sp., July.

Dr. A. D. Howard's collections of nymphs were made with a fine-meshed dredging net that was drawn on lines at 25-foot intervals from the bank to the 100-foot line and from there on at 100-foot intervals. It covered several square miles of stream bed, and, although made primarily as a mussel survey, it furnishes much more comprehensive data of the insect life of the river bed under flowing water than we have hitherto possessed.

Dr. Howard's data will be published elsewhere; but it may not be out of place here to mention some facts concerning the river mayflies as evidenced by his insect collections that were sent me for determination.

In this collection of over 600 specimens, sent in vials under 102 entry numbers, more than 75 per cent was composed of the following eight species of insect larvæ, in the proportions indicated:

	Specimens.	Times occurring.		Specimens.	Times occurring.
Dragonflies:			Mayflies:		
Gomphus plagiatus	190	57	Hexagenia bilineata	38	12
Gomphus externus	67	37	Chirotenetes siccus	29	15
Stoneflies:			Polymitarcys albus	13	8
Acroneuria ruralis[a]	81	28	Pentagenia quadripunctata	5	1
Acroneuria abnormis	21	12			

[a] The *rupinsulensis* of Walsh is a synonym of this species.

The only other specimens sent in any considerable numbers were caddisworms of the genus Hydropsyche, of which 49 specimens were sent under 15 separate numbers.

The mayflies are the chief herbivores among the insects of the stream bed. That they are not more numerous there is doubtless due to the remarkable abundance of carnivorous dragonflies and stoneflies always associated with them. In this population both pursued and pursuers fall into two principal ecological groups, according as they burrow in the sand and gravel of the stream bed or live in the water above it. The mayflies of the genera Hexagenia and Pentagenia and the dragonflies of the genus Gomphus are all true burrowers, possessed of flattened and more or less shovel-like, digging, front feet (see Pls. LXXII and LXXIV), have the hind legs appressed to the body and adapted for pushing, and have the front of the head sloping forward and somewhat pointed. There are also many special adaptations to burrowing, among which none is more remarkable than the development in these mayflies upon the front of the mandibles of a pair of long, strong, upcurving, and pointed tusks that are driven forward into the soil and upon which the roof of the burrow is lifted, opening a subterranean passageway.

When a burrowing mayfly nymph is thrown out upon the surface of the sand, it digs in again more quickly than a mole. A few thrusts of the tusks forward, a few tosses of its head upward, a few side sweeps with its broad front feet, and it disappears from view beneath the sand.

The mayflies of the genera Polymitarcys and Chirotenetes and the stoneflies of the genus Acroneuria live above the stream bed and do not burrow. They prefer the shelter of stones or of timbers but occur occasionally in more open places. In Dr. Howard's collections these two mayflies are more frequently associated with one another than with any other species, and neither is once taken in association with either of the burrowing mayflies named above.

Polymitarcys and Chirotenetes have little more in common, however, than a habitat. They are very different in form and also in manner of life. Polymitarcys is a bottom sprawler, depressed, flat, hairy, protectively colored, and inactive. Chirotenetes is an agile swimmer and an artful dodger, with body compressed, smooth, and of beautiful stream-line form. It gathers its food from the passing current by means of plancton-retaining fringes of hairs that margin the fore legs (Clemens, 1917). Polymitarcys is a member of the subfamily Ephemerinæ and has for its nearest allies the burrowing mayflies above discussed. Its mandibles are tusked (Pl. LXXVIII, fig. 41), but the tusks are not upcurving and are not used for burrowing; they are laid out flat upon the bottom as are also those of the allied Euthyplocia (Pl. LXXIX, fig. 48). Chirotenetes is a member of the subfamily Bætinæ, a group in which there are no burrowers. This is the only member of the group that appears abundantly in the collections from the Mississippi River, and, beyond the figures of Plate LXXXII illustrating *Chirotenetes siccus*, the group receives no further treatment in this paper.

In January A. F. Shira, director of the Fairport station, sent me the insect contents of nine stomachs of river herring that had been collected during the two preceding seasons and observed to contain mayflies, so far as determinable, as indicated in the following table:

FOOD OF NINE SPECIMENS OF RIVER HERRING (POMOLOBUS CHRYSOCHLORIS).

No.	Date.	Locality.	Collector.	Pentagenia nymphs.	Hexagenia.			Heptagenia.	Miscellaneous.[b]
					Nymphs.	Adults or subimagos.[a]	Eggs.		
1	May 23, 1916	Keokuk, near dam	Parker	2			([c])	2	([d])
2	June 4, 1915	Keokuk		2	3		([c])		([d])
3	June 11, 1916	do			2			1	
4	June 21, 1915	do		3	3				
5	July 2, 1916	do							([e])
6	July 4, 1915	do	Stringham		Many.	Many.	([c])		
7	July 14, 1916	Lake Cooper above depot	do	1	1	200	([c])		([e])
8	do	do	do		3	100	([c])		([f])
9	Sept. 8, 1916	Keokuk, above dam				[g] 100	([c])		([a], [h])

[a] Approximate only; many badly disintegrated.
[b] The fishes named below were not sent me, having been previously determined.
[c] Occurring in large numbers.
[d] A damselfly nymph of the genus Argia.
[e] 1 Hiodon and 4 undetermined fishes.
[f] 2 Hiodon, 4 Dorosoma, 10 undetermined fishes.
[g] Of recognizable specimens all were females.
[h] 20 caddisflies of the family Leptoceridæ.

Evidently, during the season of flight of Hexagenia, this fish gorges itself with adults. Earlier it eats the nymphs. The eggs found might about equally well be obtained from nymph or adult, since they are matured, so far as external aspect is concerned, during the nymphal period.

SYSTEMATIC ACCOUNT OF THE GROUP.

The burrowing mayflies and their allies comprising the subfamily Ephemerinæ include in North America half a dozen genera of rather large species. Among these are the largest of our mayflies, the "brown drakes" of the genus Hexagenia, which by reason of their enormous swarms are known to everyone; the "yellow drakes" of the genus Pentagenia; the beautiful "mackerels" of the genus Ephemera, with ornate color patterns on both wings and body, and most graceful and lively nuptial flight; and several genera of smaller and less familiar mayflies. These will be characterized and illustrated and an account of their habits so far as known will be given in the following pages.

The group of the burrowing mayflies may be distinguished from other groups, and the genera of the group may be distinguished from each other in both adult and larval stages as follows:

KEY TO THE SUBFAMILIES OF EPHEMERIDA.

A. Adults.

1. Basal fork of the cubital vein[a] strongly unilateral; cubital and first anal veins strongly divergent at base . . . . EPHEMERINÆ.
   Basal fork of the cubital vein symmetrical, or nearly so; cubital and first anal veins at base parallel or very slightly divergent . . . . [b] BÆTINÆ and HEPTAGENINÆ.

B. Nymphs.

1. Mandibles with a prominent, tusklike, external branch projecting forward from the mouth and visible from above . . . . EPHEMERINÆ.
   Mandibles not "tusked" . . . . [b] BÆTINÆ and HEPTAGENINÆ.

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[a] The terminology of the venation of the wings is illustrated and explained in Plate LXXXI, figure 55.
[b] Not here treated.

KEY TO THE NORTH AMERICAN GENERA OF THE SUBFAMILY EPHEMERINÆ.

A. Adults.

1. The posterior fork of the median vein in the fore wing very deep, almost reaching the base of the wing; two long simple intercalary veins between the first and second anal veins......Campsurus.
   The posterior fork of the median vein not extending more than three-fourths the distance to the base of the wing........ 2.
2. Between the first and second anal veins is a bunch of three or four long, straight, intercalary veins conjoined basally before their attachment to principal veins; the second anal vein is nearly straight, and unbranched ....Polymitarcys.
   Between the first and second anal veins are only shorter, sinuate, and sometimes forking intercalary veins, that are attached directly to the first anal vein; the second anal vein is sinuate and often branched........ 3.
3. The posterior fork of the median vein extends two-thirds to three-fourths the distance to the base of the wing; vein Cu_2 not more strongly curved at the base than is the first anal vein. .Euthyplocia.
   The posterior fork of the median vein less deep, not longer than its stem; vein Cu_2 more strongly curved at its base than is the first anal vein........ 4.
4. The third anal vein not forked, but attached to the hind margin of the wing by a series of cross veins; forceps of the male 4-jointed........ 5.
   The third anal vein ends in a single fork and is not attached to the hind margin of the wing, though a few isolated intercalated veinlets lie between; male forceps 3-jointed...........Potamanthus.
5. Tails 3 in male and female; fore wings with a definite and beautiful pattern of spots. .Ephemera.
   Tails 2 in the male; fore wings diffusely marked or plain........ 6.
6. Tails 3 in the female; mature color predominantly yellowish ....Pentagenia.
   Tails 2 in the female; mature color predominantly brownish ....Hexagenia.

B. Nymphs.

1. Unknown (tropical and subtropical) ....Campsurus.
   Mandibular tusks shorter than the head, only their tips visible from above........Potamanthus.
   Mandibular tusks longer than the head and very conspicuous........ 2.
2. Front of head rounded; legs decreasing in length posteriorly; fore legs longest........ 3.
   Labrum wider than long; tusks hairy almost to tips ....Euthyplocia.
3. Front of head produced forward and conspicuously lobed; legs increasing in length posteriorly.... 4.
   Labrum longer than wide; tusks hairy only at enlarged base........Polymitarcys.
4. Frontal prominence semicircular, shelflike........Hexagenia.
   Frontal prominence bifid at its tip .... 5.
5. Both mandibular tusk and frontal prominence denticulate externally........Pentagenia.
   Mandibular tusk and frontal prominence smooth externally ....Ephemera.

SINGLE DISTINCTIVE CHARACTERS OF OUR GENERA OF EPHEMERINÆ.

So well marked are these genera that they may be recognized at a glance by the following characters:

Adults.

Ephemera alone has the fore wings ornamented with a pattern of transverse spots.

Hexagenia alone has a border of brown on the front of the fore wing and another on the outer margin of the hind wing.

Pentagenia alone has the transverse row of four dots on the veins, as shown in Plate LXXIII, figure 15, and a single conspicuous dorsal stripe laid lengthwise of the body.

Campsurus alone has the middle and hind legs aborted, also the greater depth of the posterior fork of the median vein, almost reaching the wing base.

Potamanthus is the smallest (expanse of wings about three-fourths of an inch), and it alone has the wings wholly transparent (the two following white-winged genera have gray or purplish margined fore wings).

POLYMITARCYS alone has three or four long, straight, intercalary veins between the first and second anal veins, joined together basally before their attachment to these veins.

EUTHYPLOCIA alone lacks all the preceding characters.

Nymphs.

EPHEMERA alone has a frontal prominence divided by a deep, round notch into two smooth spines.

HEXAGENIA alone has a rounded, shelflike, frontal prominence on the head.

PENTAGENIA alone has numerous brown denticles on margins of frontal prominence, antennal basal folds, tusks, and front tibiæ.

These three are the true burrowers, having upturning tusks, front feet flattened for digging, more or less cylindric bodies, and erect gills.

CAMPSURUS nymph is unknown.

POTAMANTHUS alone has the tusks shorter than the head.

POLYMITARCYS alone has long, smooth tusks as long as the head and hairy only at their dilated bases.

EUTHYPLOCIA alone has the enormous tusks, hairy almost to the tip and beset also externally with brownish prickles.

These last three are the sprawlers, having tusks horizontally extended, elongate fore legs, and laterally extended gills.

HEXAGENIA, the Brown Drakes.

This genus includes the largest of our mayflies, measuring often an inch and a half in expanse of wings and nearly an inch in length of body, to which the long tails may add 2 inches of length; all this without counting the very long fore legs which are usually extended forward. The fore wings are marked with a brownish band along the front border, and there is usually a narrower border of brown around the outer margin of the hind wings. This color varies from a faint, brownish tinge in newly emerged individuals and in pale varieties to dark brown, almost black, in older ones or in other varieties; and when these bands are darker, then the cross veins of the middle area of both wings become bordered with brown. The body is brown above, yellowish beneath; there is a paler longitudinal middorsal stripe upon the thorax, dividing the brown into two broad stripes, as in the typical *H. bilineata* Say; and there are interrupted yellowish rings upon the abdomen, all of which pale markings tend to become obscured in the darker specimens.

Hexagenia bilineata is the name I apply to all the variants of the species that occupies the beds of our larger lakes and streams. The color differences appear to be only differences of degree. Even the differences of the male genitalia—usually our ultimate criteria of species—are intergradient.

Walsh (1863) thought there were two good species in the Mississippi River at Rock Island. He said (p. 199):

> Nothing is easier than to distinguish the living specimens of these insects [*H. bilineata* and *H. limbata*=*variabilis* Eaton] by the color of the eyes. In the former the upper half of the eyes is cinnamon brown, in the latter bright, greenish yellow; in both the lower half of the eyes is black. The dried specimens, especially those of the male, are very difficult to distinguish. * * * In the middle of July, when on the shallow area of the Mississippi known as "the slough" at Rock Island, *H. bilineata* appears in prodigious swarms, so that the bushes absolutely bend down with their weight. * * * I am sure that in the thousands of individuals, both male and female, which blackened the bushes there was not one with the upper surface of the eyes yellow or yellowish; the only variation I noticed from the normal color was that one male had the eyes a shade or two paler than the rest on their upper surface.

I have not had the privilege of studying the Hexagenias of the Mississippi River alive, but I am unconvinced by this emphatic opinion and by the long table of other color differences that he gives on the following page (1863, p. 200); for I fear Walsh did not take into account the color differences due to age, and, though he examined thousands of specimens at a time, these thousands may well have been all of practically the same age—all of one day's brood.

Several forms have been named upon the basis of slight and inconstant color differences. Dr. Hagen (1890) thought to reduce the species to two in number because of differences he found in the form of the penes of the male, whether gently curved and fingerform (*bilineata*) or hooked and pointed (*limbata* Pictet = *variabilis* Eaton). I thought for a long time I could recognize males of these two species; and in my earlier papers I have treated *variabilis* as a distinct species, but a careful study of more material has shown intergradients and additional forms. Four of the more typical forms of male appendages are shown in Plate LXXXI, figures 61, 62, 63, and 64. In a general way it may be stated that the long, straightish penis goes with the lighter coloration of wings and body and with northward distribution; but there are exceptions to this also. A separation of species on such characters as these should not be made without a careful study of at least two things:

1. *Changes of form due to age.*—A casual examination of the subimago, when the penis of the adult is clearly outlined within that of the subimago, shows that there will be a considerable change of form at the final molting. Figure 65 of Plate LXXXI shows this condition. The inclosed penis, it may be seen, will be of the form shown in figure 62 of the same plate.

2. *Changes due to functional activity.*—There is a relatively immense sperm mass gathered at the outlet of the vasa deferentia of the newly issued adult male, whose presence there may have something to do with the prominences of the penes and whose discharge may allow for much retraction.

A good many names have been applied to the different forms of this genus, but after a careful study of a good bit of material from many localities I am unable to recognize more than two good and distinct species in the eastern United States—a lowland species from lakes and rivers, *Hexagenia bilineata* Say, and an upland bog-stream species, *H. recurvata* Morgan.[a]

The former is, of all our mayflies, the most important, the most abundant, the most observed, the most characteristic of the river fauna. The adult male is figured on Plate LXXI. The female would be similar, larger in size, with shorter fore legs and much shorter tails. The nymph is figured on Plate LXXII. I have examined nymphs and exuviæ from many lake and river localities and have been unable to find any constant differences between them to indicate more than a single species.

The material for this species that I have studied is as follows:

Mississippi River material, as stated in detail in preceding pages, including adults from Emerson Stringham collected about and above the Big Dam, on dates ranging from July 12 to September 15, showing several great swarms in July and several reappearances in dwindling numbers to the end of the season; adults collected by H. E. Schradieck on the outer walls of the biological laboratory at Fairport, Iowa, July 12 (when most abundant) and 25, and August 16; nymphs collected by Dr. A. D. Howard from the stream bed of Andalusia Chute just above Fairport, showing 12 occurrences in 102 collections; fragments of hundreds of adults (mostly females) from the full stomachs of the river herring, *Pomolobus chrysochloris*, sent by Director Shira. With these were a few nymphs that were probably taken when on their way to the surface to transform; and many nymphs taken from the stomachs of the shovelfish, *Polyodon spathula*, at Lake Pepin, and sent me by Dr. George Wagner, of the University of Wisconsin. These were doubtless taken while on their way to the surface, for they were eaten just before the swarms of adults appeared and at no other times (Wagner, 1908). The particular specimens sent me bear date of June 21, 1904.

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[a] With this species we are not here concerned. It is still insufficiently described, but its determination is made possible by the figures of the genitalia that were published by Miss Morgan in the Annals of the Entomological Society of America, volume 6, page 395, 1913. Figures 8 and 12 of Plate LXXII herewith show that its nymph is readily distinguished from the lowland form by the relatively greater length of the mandibular tusks and by the unbranched condition of the rudimentary first gill. This is an early season species that swarms in May and then disappears, none being seen after early summer.

Other material made up of that collected by Prof. J. H. Comstock at Peoria, Ill., on July 17, 1887, and at Kidders Ferry on Cayuga Lake, N. Y., on July 17, 1886; by Prof. T. L. Hankinson at Walnut Lake, Mich., in June and July, 1906; by Prof. C. Betten at Buffalo, N. Y., on the 18th, the 24th, and the 31st of July, 1906, and in Storm Lake, Iowa, in June, 1902; by Prof. C. C. Adams at Ann Arbor, Mich., in June, July, and August, 1904; by Prof. George D. Shafer at Lansing, Mich., on August 16, 1906; by E. B. Williamson at Howe, Ind., on September 14, 1916; by Prof. C. R. Crosby at Columbia, Mo., on June 16, 1905; and by myself in Lake Michigan, at Lake Forest, Ill., Walnut Lake, Mich., and Cayuga Lake, Ithaca, N. Y., July and August of several years.

HABITS.—This species, though found in a wide variety of situations, prefers shoal waters whose beds are covered with soft ooze, rich in organic materials. There the burrowing is easy and food is abundant. Figure 2 of Plate LXX shows a soft-mud bank left bare by the receding stream. A portion of the mud has fallen into an undercutting current, and in the portion that remains undisturbed a section is exposed, perforated in all directions by the many burrows of the Hexagenia nymphs. Miss Morgan (1913, p. 99) has thus described the burrowing of the upland species which she studied:

> The sloping banks were mined by Hexagenia nymphs, the open burrows showing only 2 or 3 inches apart. Most of the burrows were apparent by their round openings; from some, hairy caudal setæ protruded at full length. When a nymph was pulled out it speedily began to burrow again, placing the fore legs together with the bladelike tarsi held vertically. It next pressed them forward and outward, at the same time wedging the head between them in the cavity thus made. This movement was followed by a sudden lurch of the body forward, accompanied by wriggling of the abdomen. During these motions the second pair of legs was folded close up to the body, while the third pair was held outstretched, ready to brace against the mud. These motions, rapidly repeated, enabled the nymph to bury itself in a surprisingly short time. Some of the soft ooze taken from where the burrows were most numerous was later examined in the laboratory and found to be packed with diatoms. Stomachs of two of the nymphs were found full of silt and diatoms, showing that the nymphs had found plentiful forage as they burrowed.

The length of nymphal life is unknown, possibly two years, if one may judge by the half-grown nymphs one finds in midsummer. Transformation occurs at the surface of the water and usually at night. The grown nymph swims up and floats. A rent appears in the skin of its back. The subimago suddenly emerges from this rent, its wings expanding full size almost instantly. It stands a moment on the surface and then rises and flies away to the shore. It settles on any convenient support, often alongside countless others of its kind, as figure 1 of Plate LXX testifies, and remains quiescent for about 24 hours, when it molts again and becomes fully adult. Probably on the evening of the day following its final molt (I do not know that this has been determined in any case) it flies forth over the waters with myriads of its kind, all together making a great company, filling the air and forming one of the great swarms that have been so often described and that are so well known on every stream side.

Mating occurs in the air during flight, and almost at once thereafter the female seeks the surface of the water. She flies hither and yon, dipping the surface, and then falling flat upon it with wings outspread. Her eggs are liberated in the water, just when and how has not been actually observed; but I have seen many playing above the surface of the water, egg-laden, and I have picked many from the surface, all of which have been spent females with eggs all gone.

When gravid females are injured, as by squeezing the thorax or snipping off the head, they at once extrude their eggs in two long, yellow packets of extraordinary size (similar to those of Polymitarcys, Pl. LXXVII, fig. 36). If these be placed in water, the masses crumble and the eggs tend apart in falling; thus they become disturbed on the bottom. The egg coat, which is slightly adhesive, quickly gathers a protective covering of silt and becomes well-nigh invisible.

The eggs of a single female will usually number above 8,000. The body of the female mayfly has become hardly more than a scaffolding for carrying this mass of eggs. Her mouth parts are atrophied; her alimentary canal is an air reservoir; her muscles are nearly all muscles of flight; her chief appendages are outriggers for control of flight; and her body is filled with eggs from end to end, even up into the rear of the head. To produce this great mass of eggs and to get them fertilized and back safely into the water, is her great end in life.

The habits of the young nymphs that hatch from these eggs have not been observed. Doubtless they have many enemies, such as the predacious burrowing gomphine dragonfly nymphs. They have also parasites. I found a large nematode worm filling the body cavity of one Mississippi River specimen, and most of the nymphs have their gills thickly beset with the cysts of some parasite unknown to me.

The grown nymph of *Hexagenia bilineata* may briefly be described as follows:

Length, 28 mm.; tails, 12 mm. additional; antennæ, 6 mm. Body pale, becoming purplish brown on abdomen and on gills, bare and shining on top of thorax, hairy around all margins. Frontal prominence of head shelflike, elliptical in outline when viewed from above, marked with a median dark dot, its margin fringed with pale hairs. There is a densely hairy circular ridge or fold surrounding the bases of the antennæ externally. The long, strong mandibular tusks are bare and shining brown in color at their extreme tips, but bear a marginal line of hairs externally, the fringe becoming longer and denser toward the base.

Prothorax with its side margins widened by a fringe of long, horizontally extended hairs. Fore legs stout and twisted. Femur ovoid, with a small lobe beside the apical articulation, hairy in longitudinal patches, the brushes short on the sides and very long on the edges. Tibiæ greatly dilated apically and further widened by marginal fringes of hairs, with a single, large apical tooth and that close beside the base of the short cylindric tarsal joint. Claw very short and stout, not more than twice as long as wide. Middle and hind legs slender, similar, each with a pincherlike prolongation of the apex of the tibia inferiorly, beside the base of the tarsus, the prolongation bearing an obliquely placed comb of short, stiff hairs. All expanded margins of all the legs bear dense brushes of yellow hairs.

The hind wings of Keokuk nymphs show a distinct outer border of brown.

Abdomen purplish brown above, darker on the middle segments, on each of which is included a pair of oblique, pale marks that are divergent at the rear. Gill on abdominal segment 1 rudimentary, tuning-fork shaped; on 2 to 7 large, composed of nearly equal lanceolate, long-tapering divisions that are broadly margined with whitish respiratory filaments. Tails stout, tapering broadly, fringed each side with tawny hairs, the very slender tips bare.

PENTAGENIA, the Yellow Drakes.

This is another genus of very large mayflies. These are almost as large as the brown drakes but have shorter legs and tails. The prevailing color is yellowish, but there is a wide dorsal band of obscure brownish laid upon the body its entire length; the wings are only tinged with yellowish along the front border.

There is, I think, a single species of this genus in the Mississippi River, though Walsh described two. I call them all, therefore, by the name he first used, *Pentagenia vittigera;* for *Pentagenia quadripunctata*, the form with four dots on the veins of each fore wing (figured on Pl. LXXIII herewith), appears to be only a variant. The conspicuousness of these dots is exaggerated in the figure; in a series of specimens some will be found in which one can hardly tell whether the dots are present or absent.

This genus is very insufficiently known. Nothing has been published hitherto concerning it except bare and incomplete descriptions of the adult. Mr. Stringham's brief notes, cited in the preceding pages, are the first that deal with habits; and his care in collecting subimagos, together with their cast nymphal skins, make it possible to identify with certainty the immature stages. The nymph is described below and is figured on Plate LXXIV.

My specimens of Pentagenia are all from the Mississippi River. (It is reported in Banks's Catalogue elsewhere only from Kansas.) The dates of adults range from June 16 to September 7, with maximum occurrence in late June. Transformation was observed by Mr. Stringham at 7.30 p. m. on June 25. Mr. Schradieck's imagos from Fairport, Iowa, bear date of August 16. Dr. A. D. Howard encountered the nymph in the bed of Andalusia Chute only once. There is a single nymph sent me besides, bearing the label H. McAdams, Keokuk.

The nymph of Pentagenia is similar to that of Hexagenia but is more yellow and more hairy, and a glance at the denticulations of the front of the head is sufficient for certain identification. It may be described as follows:

Length, 24 mm.; tails, 6 mm. additional; antennæ, 4 mm.

Color pale yellowish, deepening to brownish posteriorly on the dorsum, whitish below. The head in front, the legs exteriorly, and the lateral lobes of the abdomen are densely clothed with shining, golden hairs. Eyes and ocelli black.

The diffuse brown of the thoracic dorsum becomes a broad definite longitudinal stripe on the abdomen, nearly as wide as the segments. On each segment a pair of obliquely placed pale dashes is included in the brown.

Antennæ wholly pale and naked. Head with a strongly chitinized, two-toothed, frontal prominence, and a ridge bearing two unequal denticles above the base of each antenna. Cheeks and outer edges of palpi densely clothed with brushes of yellow hair.

Mandibular tusks very strong, bare and upcurving in their apical third, dilated basally and bearing an external carina that is edged with irregular, brown denticles. This portion of the tusk is hairy within, and at the base externally.

Top of head and thorax smooth, shining, save for some short, yellowish pubescence about the wing roots.

Legs short and heavy, hairy on front and rear margins, especially the front legs. Front femora flattened and quadrangular, with an expanded inferior lobe beside the knee joint that bears an immense brush of stiff, yellow hairs. Front tibia dilated apically and bearing a similar inferior lobe that is densely clothed with shorter, stouter bristles; bearing also an external denticulate-margined ridge of increasing prominence distally where it ends in a strong and conspicuous brown tooth. Just beyond this, at the apex of the tibia, another similar tooth lies against the base of the short cylindric tarsal segment. There is an angulate line of long, thin hairs extending across the tibia near its base on the inner side. These hairs are outspread, fanlike beneath the mouth, meeting from the two sides, and may serve as a sort of table to hold up the food convenient to the jaws. The front tarsus is hardly longer than the tibia is wide; its claw, a third as long, is short and thick and curved and abruptly tapering. Middle and hind legs are more slender and less hairy; third tarsi are longer, with claws of equal length, more slender and tapering.

The wings of the nymph show four round, black spots at the points where dots will appear in the wing of the adult (see Pl. LXXIII, fig. 15), and two additional larger pigment spots that do not reappear in the adult—one on the posterior fork of the median vein and one on the rear end of the humeral cross vein.

The abdomen is nearly cylindrical, nearly covered above by the bushy, purplish gills. The lateral margins of segments 3 to 7 just outside the gill bases are expanded with bluntly rounded, lateral lobes that are densely clothed externally with golden-yellow hairs. These lobes increase in size to the fourth segment and then diminish in size posteriorly. The two divisions of the gill are unequal, the posterior being reduced in length, especially on the anterior gill-bearing segments. The tails are rather short and stout and thickly fringed with hairs.

EPHEMERA, the Mackerels.

This is a genus of beautiful mayflies, somewhat smaller in size than the two preceding, with relatively longer fore legs and tails. The cross veins of the front and middle portions of both wings are bordered with brown, and on the middle of the fore wing the brown is confluent in a series of spots arranged in a beautiful pattern. (See Pl. LXXV.) By this pattern our adult mackerels may all be easily recognized.

The mackerels are lacustrine rather than fluviatile in habitat, especially *E. simulans*. The shores of the Great Lakes swarm with this species during early July, and on the Finger Lakes of New York they are only a little less abundant.

The poorly differentiated species, *E. varia* Eaton, seems to prefer the little lakes and ponds and the muddy pools of stream beds.

I have already published a description and figures of the nymph of *E. varia* (1901, p. 429). Miss Morgan has also figured it (1913, Pl. XLIV, fig. 8) and has added the following interesting notes on the habits of the species at Ithaca (p. 100):

> No Ephemera nymphs were found in lower Fall Creek up to this time, that cleaner portion being nearly devoid of mud. On the first of July, however, the water in Beebe Lake was allowed to run off, bringing into the Lower Creek large quantities of mud. Three days later the shores below the dam were again examined. Tracks similar to those made by earthworms covered the bottom near the shore line. Nymphs were crawling over the surface and setæ could be seen projecting from many burrows. From an area of about 10 square feet 30 nymphs were removed.

From this it appears that this species seeks out the muddy pools in even so turbulent and rocky a stream as is Fall Creek.

E. varia is but doubtfully distinct from *E. simulans*. The wings of the typical form are less suffused with brown; the tip of the penis is a little more squarely truncated, and the proportionate length of the segments composing the forceps is slightly different; but none of these differences is either very tangible or very constant. I present new figures of the adult of *E. varia* on Plate LXXV, of its nymph on Plate LXXVI, and of the male genitalia of the three nominal species of the northern United States (these two and the very distinct *E. guttulata*) on Plate LXXXI, figures 58–60.

Concerning the habitat and habits of the beautiful, but rare, broader-winged species *E. guttulata* Pictet no information is available. I have not seen that species alive, and the only specimen I possess is a fine male that was collected for me.

So, again, in this genus there is a single species commonly occurring in the larger lakes and streams; and to that species mainly the following remarks will apply.

I have observed *Ephemera simulans* during several seasons at each of two places on the Great Lakes—at Lake Forest, Ill., on the shore of Lake Michigan, and at "Afterglow," my summer home near North Fair Haven, N. Y., on the shore of Lake Ontario. In both of these places the lake bed is sandy and not muddy. In neither place have I seen Hexagenia at all. Ephemera is the dominant form and the sole representative of the group here discussed, and it is associated in its swarming with several mayflies of other subfamilies and with a number of exceedingly abundant caddisflies.

The swarms of *Ephemera simulans* arise less suddenly than do those of Hexagenia and decline more steadily after a single maximum that is reached about the first week in July. For many days together the herbage of the shores and the trees upon the bluffs are thickly besprinkled with adults for more than a stone's throw inland from the shore. Then, after sundown, when they rise to enter upon their nuptial flight, the air is darkened with the clouds of them that extend in an unbroken line along the margin of the water. At Lake Forest, with an on-shore breeze their cast skins accumulate beside the piers in great floating masses, acres in total area and several inches deep, each cubic inch of these masses representing scores of individuals. At "Afterglow" the little hop hornbeam trees that cling to the front of the bluff are constantly aflutter with the mackerels that can not find resting places without disturbing one another; and if one shake such a tree, a perfect cloud of them will rise in the air

The smallest lake at which I have studied *E. simulans* is Walnut Lake in Michigan. It is there, where the numbers are not so great and where the evening swarms are less rough-and-tumble, that I have seen their mating flight at its best. I have described this (1908*b*, p. 261) as follows:

> After sundown the beautiful mayfly, *Ephemera simulans*, appears in companies of males over the edge of the water. The flight of one of these companies is a most delightful performance to witness, it is so light and graceful, and appears, withal, so exhilarating. Yet it is all up and down in vertical lines. With upturned head each individual flies rapidly upward, mounting quickly to a height of 10 or 15 meters; then spreading its wings out horizontally it falls upon them, with long fore legs extended forward and longer tails extended backward full length, rudderlike, keeping it always head to wind. Thus it descends, floating on the air, yet not drifting, until at the lower level of the swarm (4 or 5 meters above the water), it lifts its head and rises rapidly again in flight. And the whole company flying and falling thus, weaving up and down in vertical lines, and passing and repassing each other, create a scene of great animation.

My material in this genus comes from a good many sources, none of it, however, from the Mississippi River, though doubtless the genus will yet be found in many places in that stream.

Typical specimens of *E. simulans* come from Dr. C. C. Adams, collected at Portage Lake, Washington County, Mich., on May 30 (these bear the earliest date of all); from Prof. J. H. Comstock, collected on Cayuga Lake on the 1st and 6th of July; from Dr. C. Betten, collected at Buffalo, N. Y., on Lake Erie on the 11th of July; and from Walnut Lake, Mich., Lake Forest, Ill., and North Fair Haven, N. Y., on numerous dates in the fore part of July, collected by myself.

Typical specimens of *E. varia* Eaton are from Three Mile Island, Lake Winnepesaukee, N. H., collected by J. H. Emerton on July 10, 1906; from Lansing, Mich., collected by George D. Shafer; from Gloversville, N. Y., collected by Dr. C. P. Alexander on July 26; and from many places in the Adirondacks and about Ithaca, collected by myself. Miss Morgan gives the date of the first appearance at Ithaca as June 14.

Of *E. guttulata* the sole specimen I have seen comes from Sport Island in the Sacandaga River, N. Y., and was collected by Dr. C. P. Alexander.

I have reared the nymphs of both *E. simulans* and *E. varia* several times, and have been unable to find any differences between them except a slight, somewhat intangible and apparently not quite constant difference in the shape of the notch that divides the frontal prominence into two points. This notch is in *E. simulans* typically a complete half circle, while in *E. varia* it is somewhat more widely open and forms but a segment (somewhat less than half) of a larger circle. Aside from this, the following description will apply to either species:

Length when grown, 18 mm.; tails, 8 mm. additional; antennæ, 4.5 mm.

Color yellowish; abdomen with a pair of longitudinal brown streaks laid on the yellow which they divide.

Antennæ slender, twice the length of the mandibular tusks, thinly hairy above on basal half and naked thereafter to slender flexuous tips. The frontal prominence ends in a sharp tooth at either side, the two separated by a rounded notch in front. Mandibular tusks long, slender, upcurved, brown in color, and nearly naked. Maxillary palpi long, slender, thinly hairy, yellow.

Legs moderately stout and somewhat flattened and twisted, clothed with tawny yellowish hairs on all exposed edges. All femora oval, fore tibia moderately flattened, widened from base outward only to midway its length, then parallel sided with an obtuse, bristle-covered, apical angle, but with no accessory apical tooth. Tarsus more than twice as long as wide and more than half as long as the tibia. Hind tibia prolonged beside the tarsus into a forcepslike joint, which is nearly wanting on the more normal middle legs.

Wing cover of the grown nymph shows a transverse series of spots, which are those of the adult more closely grouped.

Gills mainly yellowish, purplish only along the main axis. On segment 1, a bifurcated rudiment; on segments 2 to 7, large, bushy, the two divisions of about equal size. Tails thinly margined with tawny hairs.

POLYMITARCYS, the Trailers.

These are mayflies of medium size, having broad, white wings. The fore wings bear a border of dull, purplish color along their entire front margin. The legs are rather short, except the fore legs of the male, which are very long. The tails are very long.

There is a single known North American species, *P. albus* Say. An adult female with protruding egg masses is shown in Plate LXXVII. The nymph is shown in Plate LXXVIII.

The best account of the species is that given by W. E. Howard (in Needham et al., 1905, pp. 60–62), who studied it at Ottawa, Ill., from which account we quote a portion:

> Nymphs of *P. albus* are abundant in both the Illinois and Fox Rivers at Ottawa. These rivers flow at this place over bottoms of solid sandstone, with bars of loose sand accumulated in the eddies. The streams are swift in the main currents, and the nymphs of this species are to be found under flat stones at the edge of swift water when about ready to transform. It was from two such situations that most of my collections were made, from which I succeeded in breeding a single specimen. I have seen the subimagos emerge and arise from the surface of the water in great numbers, but always just far enough out from the shore, so that the nymph skins were immediately swept into the current, where they disappeared before they could be procured. The difficulty in collecting the skins from the natural breeding places is further heightened by the emergence occurring during the evening twilight. All emerge from the nymph skin at the surface of the water and leave the skin afloat.
>
> This is a midsummer species in northern Illinois. My bred specimen is dated June 22. None of the imagos in my collections shows an earlier date than this, but I have nymphs which are evidently

near to transforming which were collected the first week in June. Imagos and subimagos of the collections are scattered all through July, but August 5 shows them most abundant. At about this date they were observed in swarms. By the end of August they are much less numerous, and I have no collections which are as late as September.

The subimago stage lasts 24 hours, and when the final emergence takes place the subimago alights on some object near the edge of the stream, where it transforms in less than a minute. The skin of the subimago remains attached to the bases of the setæ of the imago and in this manner is carried out over the stream by the flying insect, where it is finally released after some minutes.

Miss Morgan found this species in Fall Creek at Ithaca on June 20, the earliest date on record. I have received specimens from points on the Susquehanna River and from Corning on the Chemung River in southern New York, those from the latter place bearing date of August 20. Say found it swarming on Lake of the Woods, United States, Canadian boundary.

Mr. Stringham's single entry concerning this species is as follows:

August 6.—Small, white mayflies have been common for at least a week or two about the river, though I have never seen any of them on the dam. Collected a few this evening at 6.45. In the morning there are many dead ones, but I never saw a live one in the day.

His specimens bear date of August 5 and 6, and those of Mr. Schradieck from Fairport, Iowa, bear the later date. So far as scattered records at present indicate, this species comes on slowly and reaches its maximum of swarming in early August.

The species is probably much more widespread than present records indicate. Usually it is not abundant; it is pale and inconspicuous in coloration; it is quiescent in habits; it is crepuscular in flight; it is rarely noticed.

The nymph does not burrow, but lies flat upon the bottom, with its legs and tusks and tails outspread upon the sand. It is protectively colored (see Pl. LXXVIII, fig. 39) and very inconspicuous. As noted before, it is an associate of Chirotenetes, and, like that species, its front tarsi bear two lines of long setæ within, the hairs of the two lines diverging and extending forward when the legs are outspread. Observations are lacking on this species, but it seems probable that it also uses these fringes as strainers to gather plankton and other food out of the passing current.

The full grown nymph may be briefly characterized as follows:

Length, 15 mm.; tails, 7 mm. additional; antennæ, 4 mm.

Body depressed, widest across the thin, flaring, lateral margins of the prothorax, smooth. Color brownish, with faint marmorate markings on thorax, and a line of pale elongate spots laid upon and crossing the sutures between the abdominal segments; gills pale.

Head broadly rounded. Antennæ pale, bare. Mandibular tusk much shorter than the antennæ, swollen at the base beneath the head, where clothed externally with many prickles and a few hairs, the tips long and slender and bare, very gently incurved.

Prothorax widest across the front, where the thin, lateral margin is most expanded, and ends in a sharp angle directed forward just outside the rear of the head.

Legs long, especially the fore legs, pale, but ringed and banded with brown and hairy along the edges; femora moderately flattened, twice banded; fore tibia and tarsus elongate and double fringed internally with long hairs; the long, straight, apical tibial spur is closely applied beneath the basal fourth of the tarsus, and a similar shorter spur at the tip of the tarsus is extended beside the sharply decurved claw.

Abdomen depressed and with gills widely extended laterally. The gill on segment 1 is an erect, simple, hairy rudiment, on 2 to 7 double, composed of flattened tapering filaments. The lateral margins of the segments are rounded in front and angulate at the rear beside the gill bases. Tails rather stout segments ringed with short, pale bristles.

EUTHYPLOCIA, the Flounders.

This is a large, white-winged species, similar in aspect to Polymitarcys, but the dark, front border of the fore wings is more diffuse, showing a tinge of sepia or even roseate warmth of color, and the wing tips are hooked and so strongly corrugated lengthwise that the venation of the tips is difficult of examination. This is a tropical American genus likely to be taken only on our southern border. The type species *E. hecuba* Hagen is from Vera Cruz.

The unidentified nymph of which I present a figure in Plate LXXIX, was collected by E. B. Williamson in Gualan, Guatemala. It appears to differ specifically from the unidentified nymph that was figured by Eaton on plate 29 of his monograph (1883–1886); however, that description was drawn from a cast skin; this, from a good alcoholic specimen. There are no other data accompanying these specimens.

This nymph is remarkable for its flatness and for the extraordinary length of its tusks and antennæ. This species may be briefly described as follows:

Euthyplocia sp.

Length, 29 mm.; tail, 12 mm. additional; antennæ, 15 mm. Color grayish brown, including the gills; antennal legs and setæ yellow. Head and body depressed, widest across the prothorax.

Head short and thick, depressed, wider than long, bare and shinning above, hairy about the mouth. Antennæ very long, slender, flexuous, and bare. Mandibular tusks very long, sickle-shaped. Stout to near the tip when suddenly narrowed to bare brown points, hairy on both inner and outer margins, the outer margin and dorsal surface beset as well with brownish prickles.

Prothorax broadly depressed with flaring parallel side margins; anterior angles more broadly rounded and incurved to a low, obtuse tooth at rear of head each side. Mesothorax with a low, thin, lateral lobe each side above the base of the middle leg, at front of segment, and strongly tapering rearward.

Legs strong, thickly fringed with hairs in all exposed lateral margins, femora flattened and marked above with scarlike, longitudinal, bare areas. Fore tibia longer than its femur and prolonged still further by a long, straight spine that lies closely beneath the tarsus for more than half its length. Tarsus similarly prolonged in a spur beneath the short, tapering claw. Middle and hind legs smaller, with only short apical prolongation of tibiæ. Wing cases uniformly purplish brown.

Abdomen long, depressed, slowly tapering posteriorly, bordered by the wide fringe of the extended gills. A pale middorsal line emerges conspicuously on the posterior segments. The lateral margins also are pale, and there are obscure, paired, pale dots in the brown of the sides. Gills on segment 1 erect, simple rudiments; on segments 2 to 7 double, long, flattened, and copiously fringed with filaments. Tails very long, flexuous, and nearly bare.

POTAMANTHUS, the Spinners.

This genus includes the smallest and daintiest of our Ephemerinæ. They are white, faintly tinged with yellow in one species, *P. flaveola* Walsh, and with green in the male of the other, *P. diaphanus* Needham. They have an expanse of wings of something less than an inch, with white tails of the same length. There are minute fuscous markings on the tips of the segments of the fore legs of the male and on the middle cross veins of the fore wings of the female of *P. flaveola* that are entirely wanting in *P. diaphanus*. Only these two American species are known.

The former (Pl. LXXX) is the species occurring in the Mississippi River. I have specimens of it also from Lansing, Mich., and from Ithaca, N. Y. Miss Morgan (1913) has published an excellent figure of the nymph, copied herewith on Plate LXXXI as figure 56. She says that "in Fall Creek Potamanthus crawls upon silt-covered stones and muddy bottoms." Eaton (1883–1886) says of the European *P. luteus*: "The nymph harbors under stones in gently flowing water at the borders of rapids." The other published observations on the habits of the group are those of Betten (in Needham, 1908*a*, p. 194), as follows:

> Returning on the boat from Buffalo I happened to look up, and saw a swarm about 20 feet above the water. I was able to take a few, but most of them were out of reach from the upper deck. It was too dark for me to see the manner of their flight. I returned next evening for further observation, but a strong wind prevented. I found the cast skins, however, belonging to this species floating upon the water and drifting upon the shore.

The eggs of females of *P. diaphanus* in alcohol hang in rounded, globular masses beneath the tip of the abdomen.

My material in this genus all bears dates in the month of July: *P. flaveola*, July 1 and 12 at Keokuk (Schradieck's Fairport specimens have only the month specified); and *P. diaphanus*, collected in the Niagara River near Buffalo, July 31, 1906.

The full grown nymph (Pl. LXXXI, fig. 56) may be briefly described as follows:

Length, 13 mm.; tails, 4 mm. additional; antennæ, 1 mm., their tips much surpassing the tips of the mandibular tusks.

Body elongate and depressed. Prothorax wider than the head, with broadly rounded, flaring, lateral margins. Fore legs longer than the others; fore tibia much longer than femur, beset with long hairs internally and bearing a stout, straight, apical spur about half as long as the tarsus. Middle legs shorter and more slender than are the hind legs. Abdomen regularly tapering posteriorly; gills rudimentary on the first segment, well developed and about equal in size on segments 2 to 7. The two divisions of each deeply fimbriate. Tails densely hairy along the middle portion, but bare at tips.

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EXPLANATIONS OF PLATES.

PLATE LXX.

Hexagenia bilineata Say.

Fig. 1. The mayflies on the gauge house on the big dam at Keokuk, Iowa, at 5.30 a. m. July 14, 1916. They were about equally numerous all along the dam, which is nearly a mile in length. Photo by Emerson Stringham.

Fig. 2. The burrows of the mayfly nymphs in a mud bank of the Okaw River near Sullivan, Ill. Burrows exposed by lowering of water in the stream and by undercutting of the current giving a vertical section. Photo by Prof. T. L. Hankinson.

PLATE LXXI.

Hexagenia bilineata Say; adult.

Fig. 3. The adult male (segmentation of the tails omitted, as in all the similar figures following).

Fig. 4. The legs of one side, fore, middle, and hind from left to right, as in the following plates.

Fig. 5. The end of the abdomen of the male from beneath, showing forceps, penes, and base of tails; middle tail rudimentary.

PLATE LXXII.

Hexagenia nymphs.

Fig. 6. The nymph of *H. bilineata* Say; dorsal view. The hind feet are turned forward for comparison with the other feet, and the gills on the right are moved aside to show the markings on the abdomen. The 3-branched, rudimentary gills on the first abdominal segment are abnormal. (See fig. 13.)

Fig. 7. Portion of head of same, more enlarged.

Fig. 8. Comparable portion of head of *H. recurvata* Morgan.

Figs. 9, 10, 11. Fore, middle, and hind legs, respectively, of *H. bilineata* Say; the front leg adapted for shoveling, the hind leg for pushing.

Fig. 12. The unbranched rudimentary first gill of *H. recurvata* Morgan.

Fig. 13. The normal bifid rudimentary first gill of *H. bilineata* Say.

Fig. 14. The functional second gill of same, showing its fringes of respiratory filaments.

PLATE LXXIII.

Pentagenia vittigera Walsh; adult.

Fig. 15. Adult male of the *quadripunctata* form.

Fig. 16. Legs of one side.

Fig. 17. End of abdomen of male from beneath.

Fig. 18. End of abdomen of female from beneath.

PLATE LXXIV.

Pentagenia vittigera Walsh; nymph.

Fig. 19. The nymph from above, with the gills on the right pushed aside to show the markings of the abdomen.

Fig. 20. Head of same from above, more enlarged.

Fig. 21. Mandible of same, showing serrated tusk.

Figs. 22, 23, 24. Fore, middle, and hind legs, respectively.

Fig. 25. A rudimentary gill of the first abdominal segment.

Fig. 26. A functional gill of the second abdominal segment.

PLATE LXXV.

Ephemera varia Eaton; adult.

Fig. 27. The adult male.
Fig. 28. The legs of one side of the same.
Fig. 29. The end of abdomen of the same from beneath.

PLATE LXXVI.

Ephemera varia Eaton; nymph.

Fig. 30. The nymph from above, gills on the right turned aside to show normal color pattern.
Fig. 31. Head of same, more enlarged.
Figs. 32, 33, 34. First, middle, and hind legs, respectively.
Fig. 35. A gill from the second abdominal segment.

PLATE LXXVII.

Polymitarcys albus Say; adult.

Fig. 36. Adult female, hovering with egg packets extruding.
Fig. 37. The legs of one side, adult male.
Fig. 38. End of abdomen of male from below, showing strongly divaricate penis tips.

PLATE LXXVIII.

Polymitarcys albus Say; nymph.

Fig. 39. The nymph from above.
Fig. 40. Head of the same, more enlarged.
Fig. 41. Mandible of the same.
Fig. 42. Maxilla of the same.
Fig. 43. Labium of the same.
Fig. 44. Fore leg of the same.
Fig. 45. A gill of the second abdominal segment.

PLATE LXXIX.

Euthyplocia sp.? nymph.

Fig. 46. The nymph from above.
Fig. 47. Head of the same, more enlarged.
Fig. 48. Mandible of the same, hairs of the tusk omitted.
Fig. 49. Maxilla of the same.
Fig. 50. Labium of the same.
Fig. 51. A gill of the second abdominal segment.

PLATE LXXX.

Potamanthus flaveola Walsh; adult.

Fig. 52. The adult female.
Fig. 53. The legs of one side of the adult male.
Fig. 54. The ventral aspect of the male genitalia, showing the form of forceps and penes.

PLATE LXXXI.

Miscellaneous (figs. 55, 56, and 57 by Dr. Anna H. Morgan).

Fig. 55. The venation of the wings of *Ephemera*.

Vein designations are those used in accompanying key; the six principal veins are: *C.* costa, *Sc.* subcosta, *R.* radius, *M.* media, *Cu.* cubitus, *A.* anal vein.

Branches of veins are marked with small numerals, in order from the front. The posterior fork of the median vein is the one in which veins M_3 and M_4 unite. R_s is the radial sector; 1 is the principal accessory vein. The third anal vein is the forked vein behind the second anal.

Fig. 56. The nymph of *Potamanthus flaveola* Walsh.

Fig. 57. An adult "Peg-leg," *Campsurus* sp.? (from Brazil), the extremely long tips of the tails omitted. Note the stubs of the vestigial middle and hind legs.

Fig. 58. Forceps and penes of *Ephemera guttulata* Pictet.

Fig. 59. Forceps and penes of *Ephemera simulans* Walker.

Fig. 60. Forceps and penes of *Ephemera varia* Eaton.

Fig. 61. Forceps and penis of *Hexagenia bilineata*, form *bilineata* Say.

Fig. 62. Forceps and penis of *Hexagenia bilineata*, form *falcata* n. nom.

Fig. 63. Forceps and penis of *Hexagenia bilineata*, form *variabilis* Eaton (syn., *limbata* Pictet).

Fig. 64. Forceps and penis of *Hexagenia bilineata*, form *munda* Eaton.

Fig. 65. Forceps and penis of *Hexagenia bilineata*, subimago, showing within the outline of the adult, form *falcata*.

PLATE LXXXII.

Chirotenetes siccus Walsh.

Fig. 66. The female subimago.

Fig. 67. Sketch of tails of male subimago to show their relative length.

Fig. 68. The female imago.

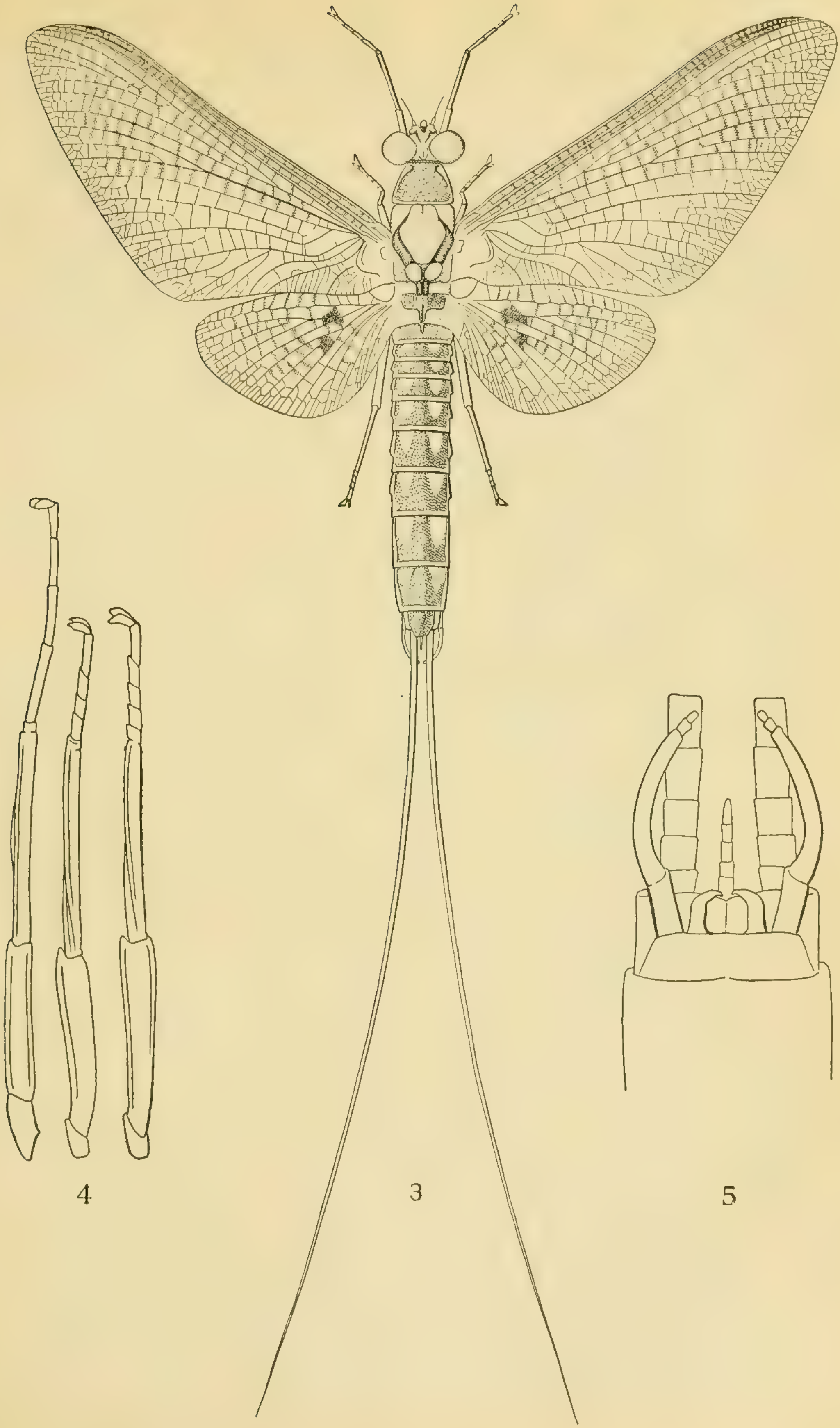
Fig. 69. Sketch of tails of male imago to show their relative length.

Fig. 70. Legs of one side of male imago.

Fig. 71. End of abdomen of adult male from beneath.

Fig. 72. The nymph from the side. Note the plancton-gathering fringes of the fore legs.

Fig. 73. The tail fin of the nymph; outer tails fringed only on the inner side.



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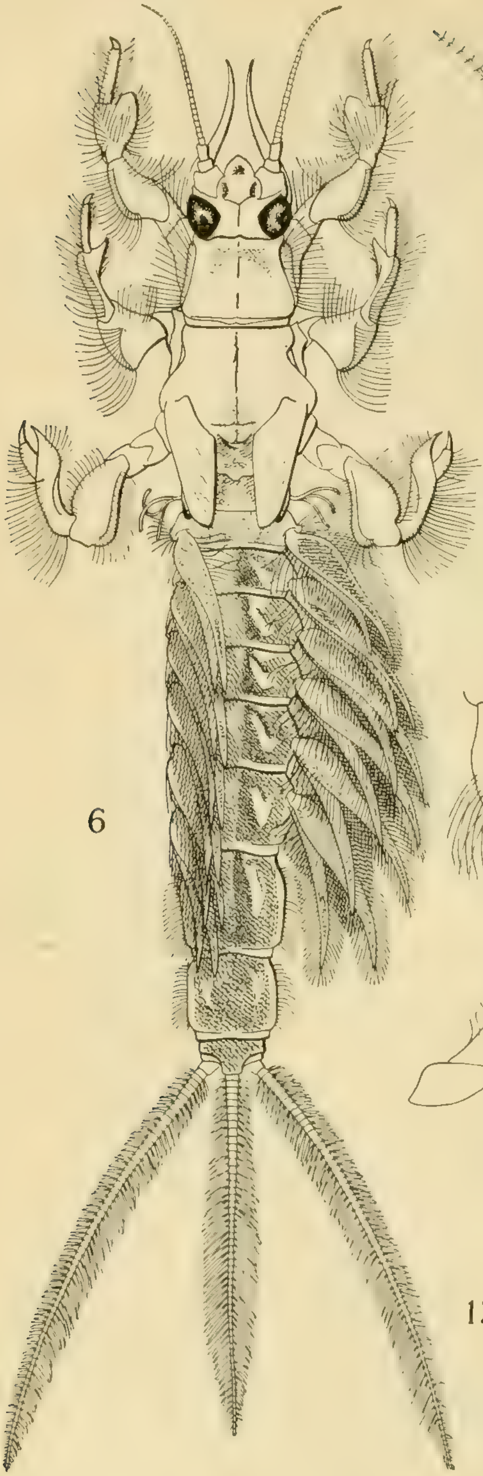
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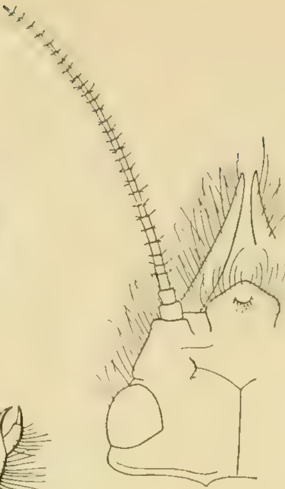
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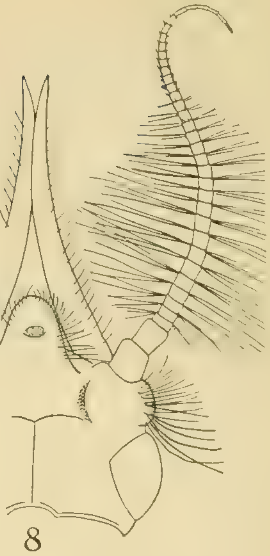
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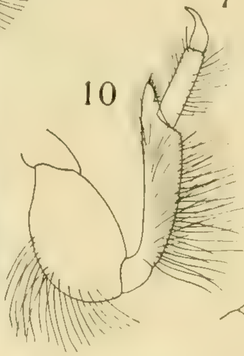
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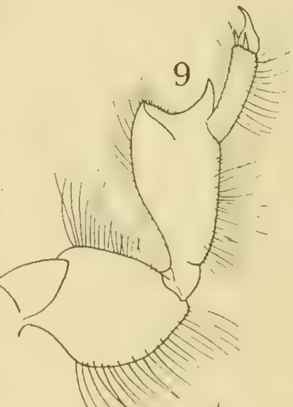
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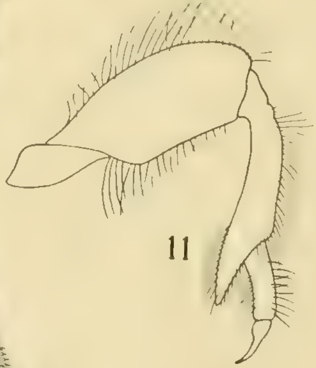
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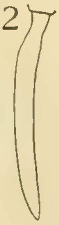
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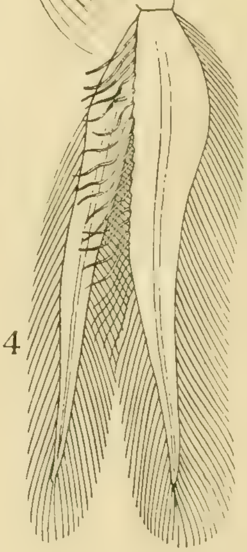
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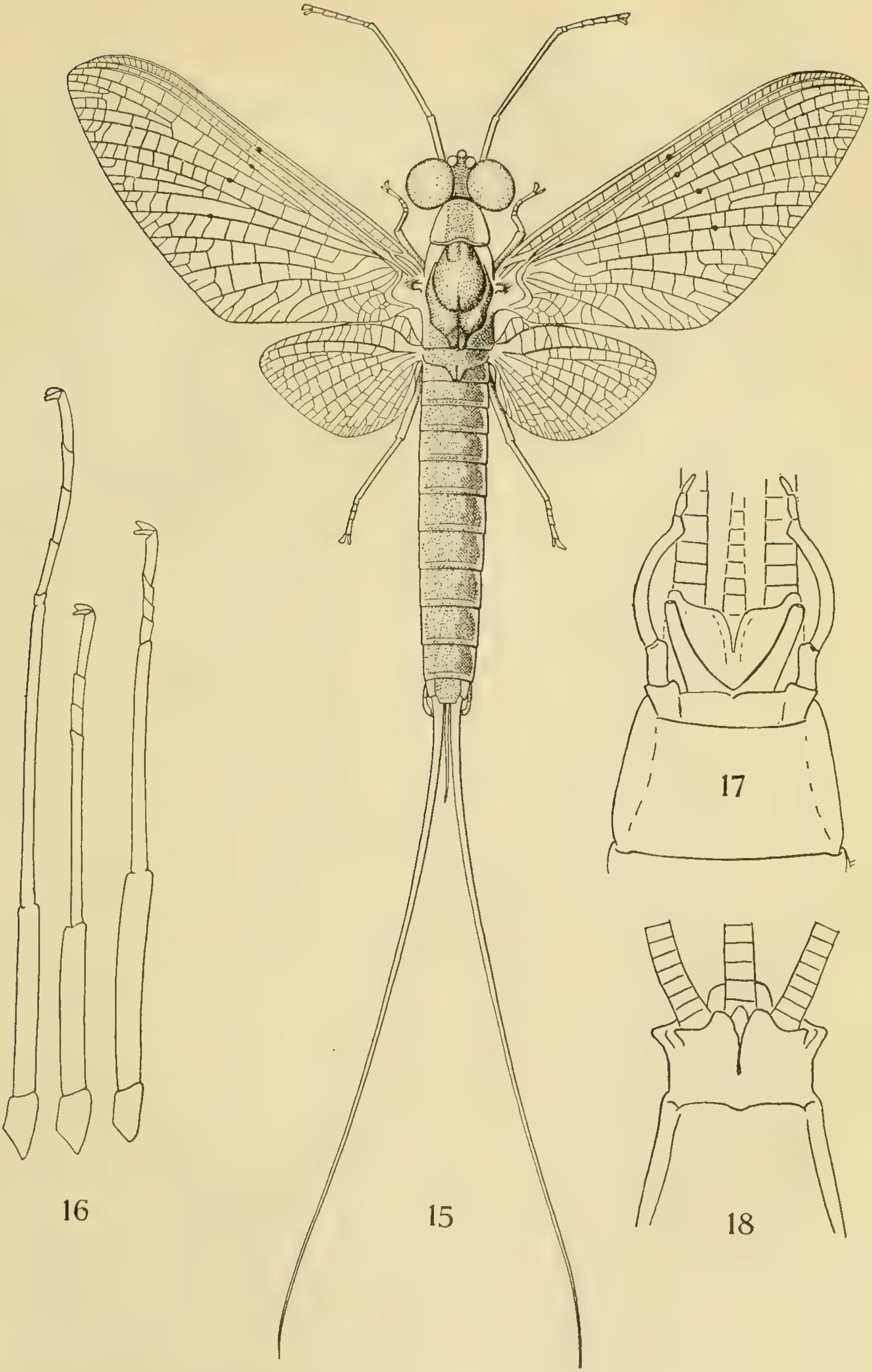

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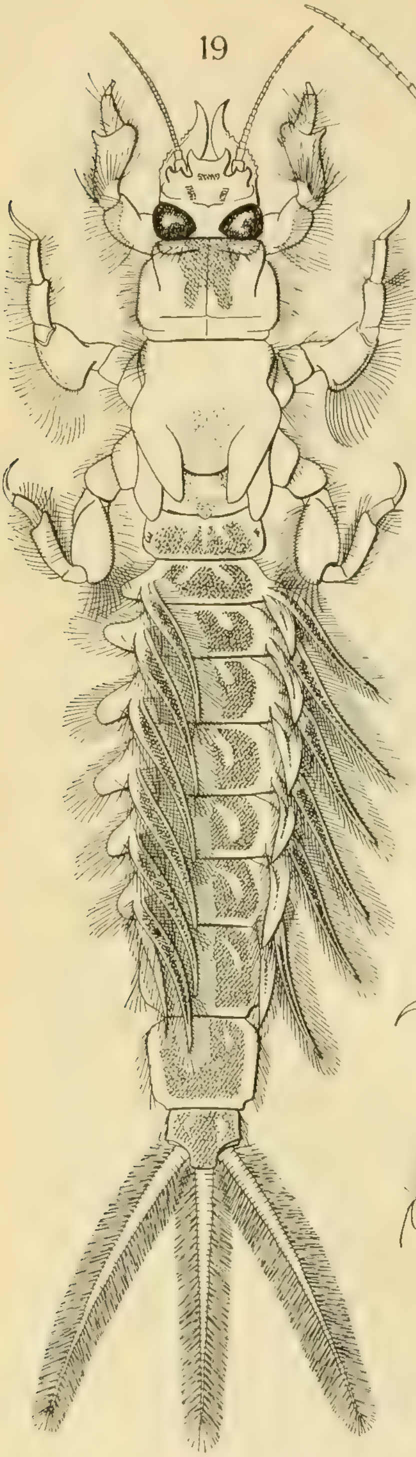

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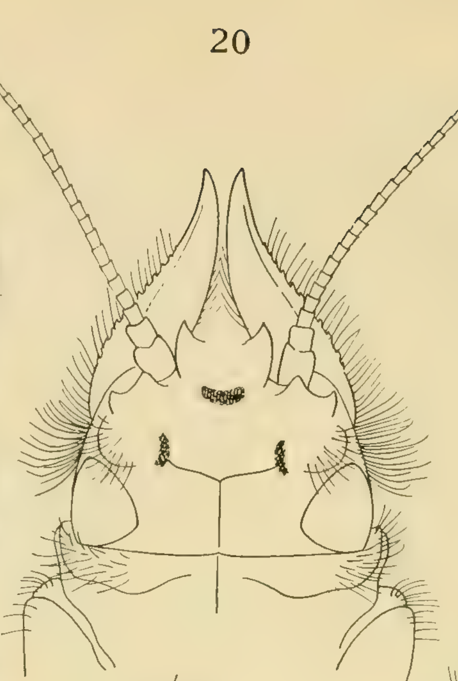

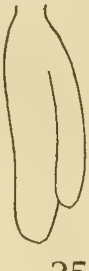

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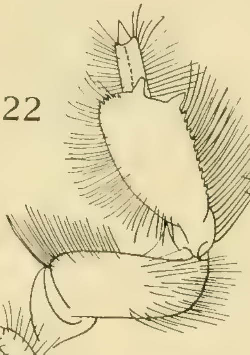

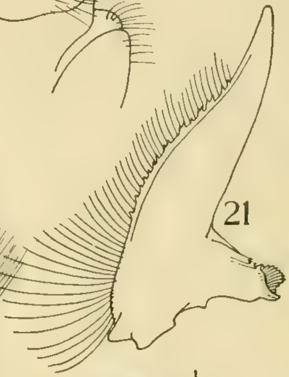

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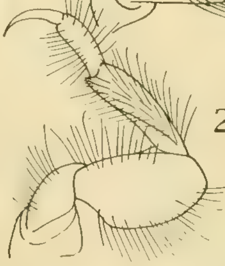

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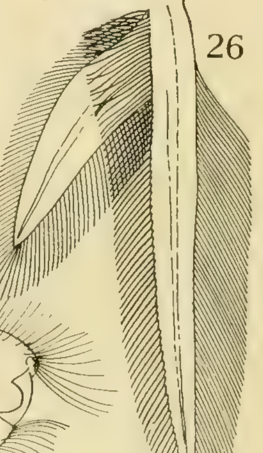

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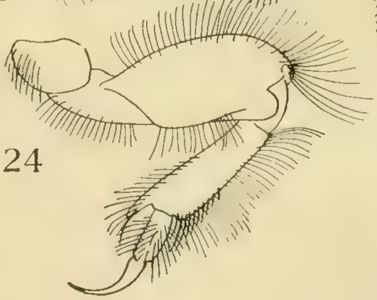

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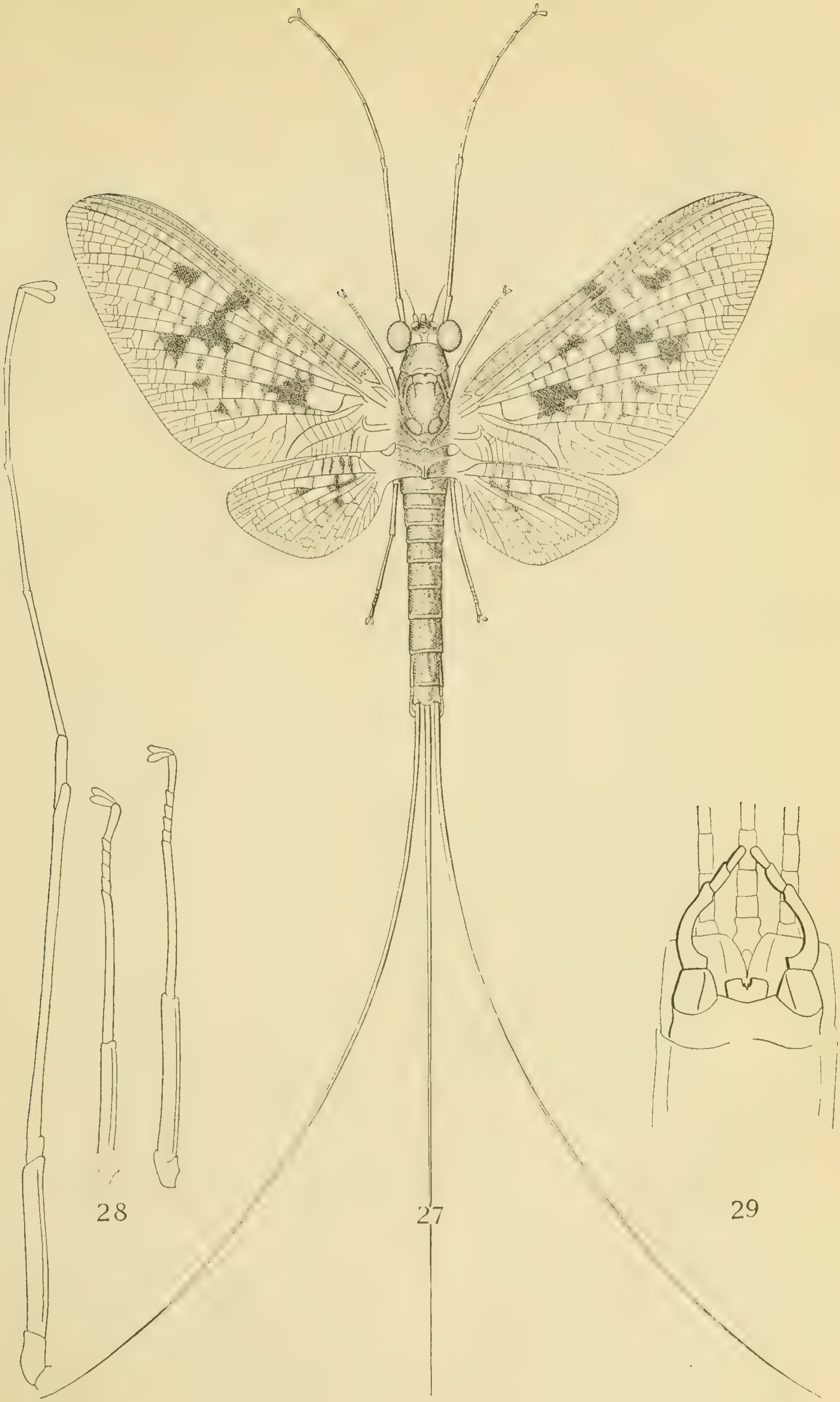

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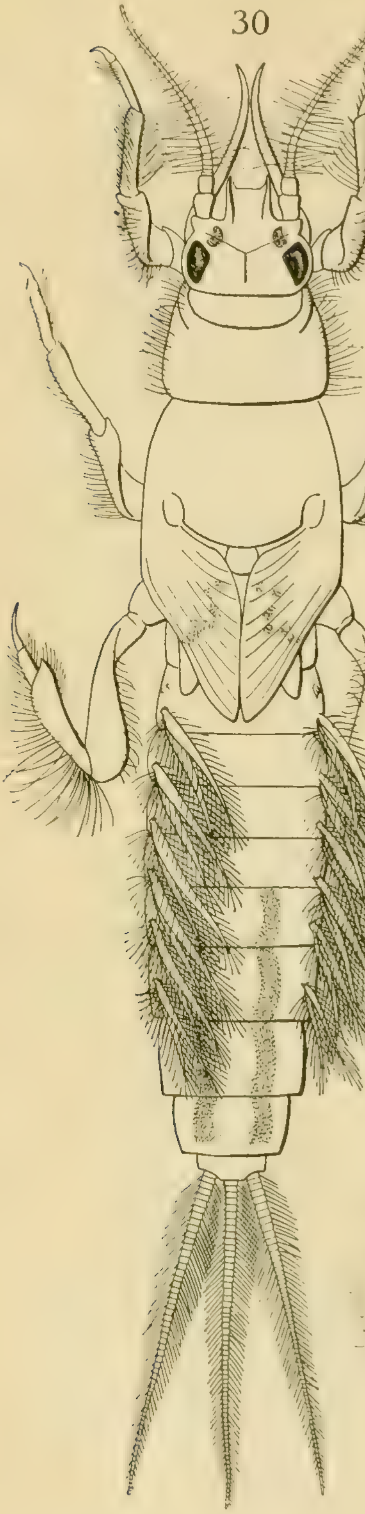

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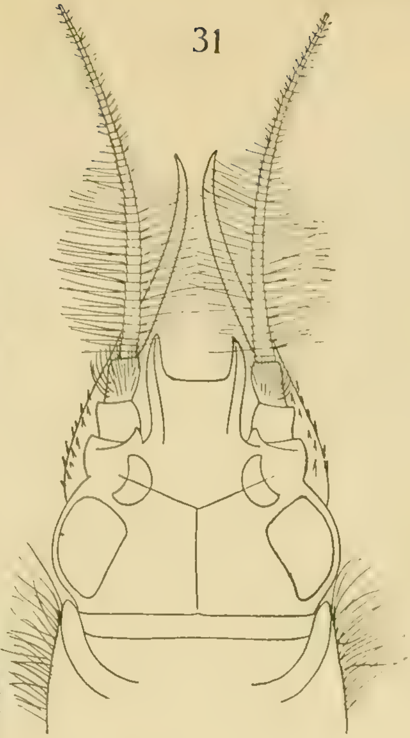

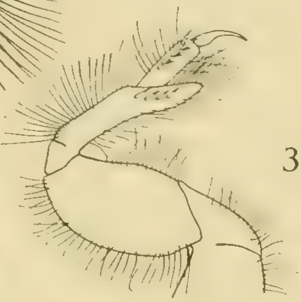

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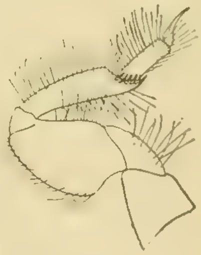

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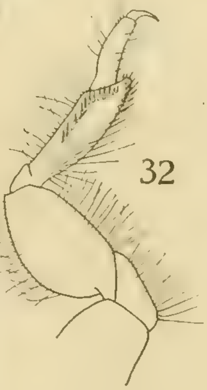

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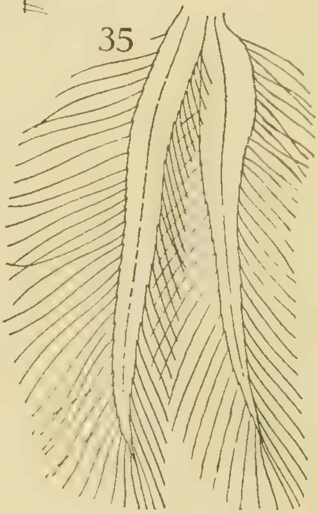

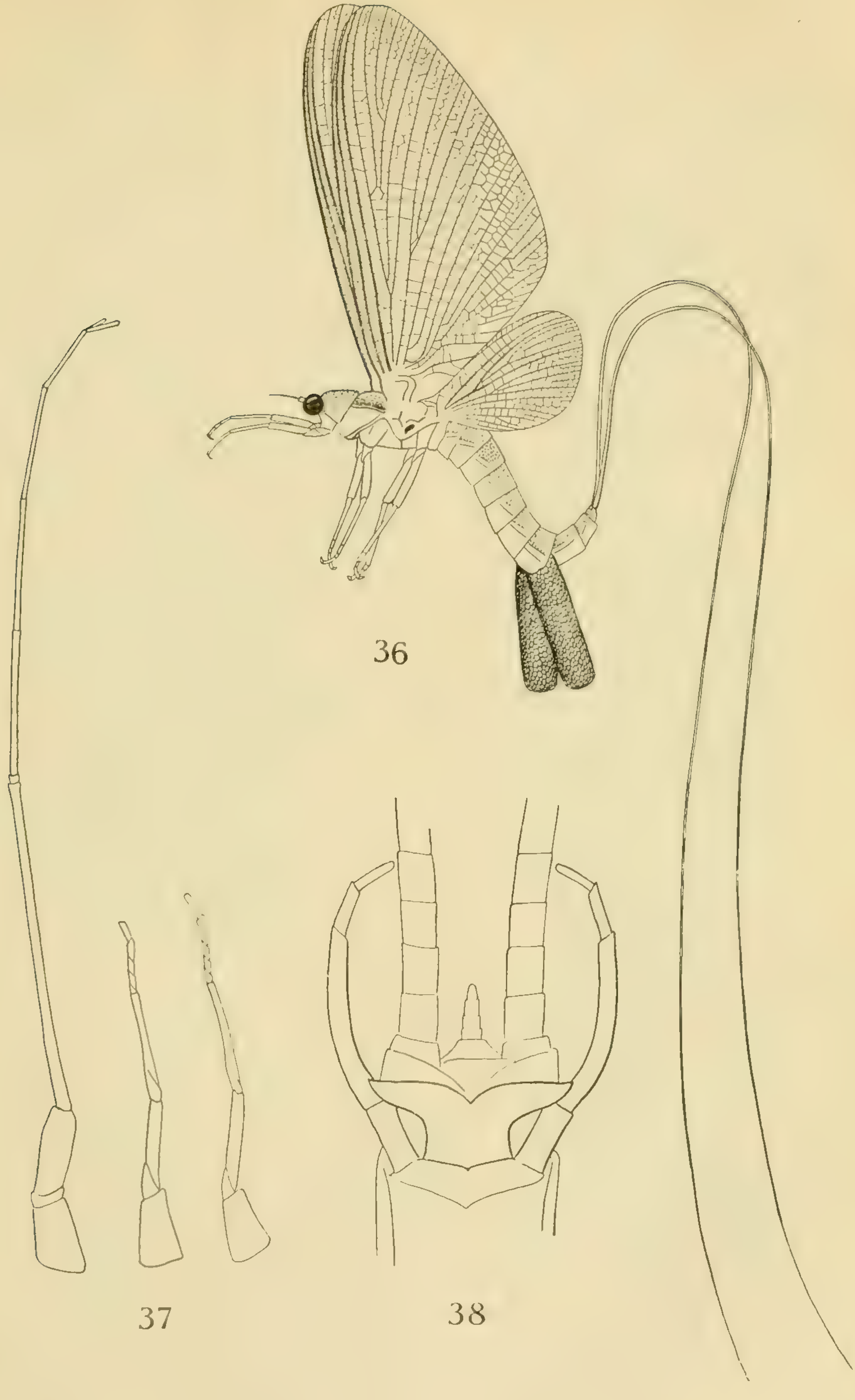

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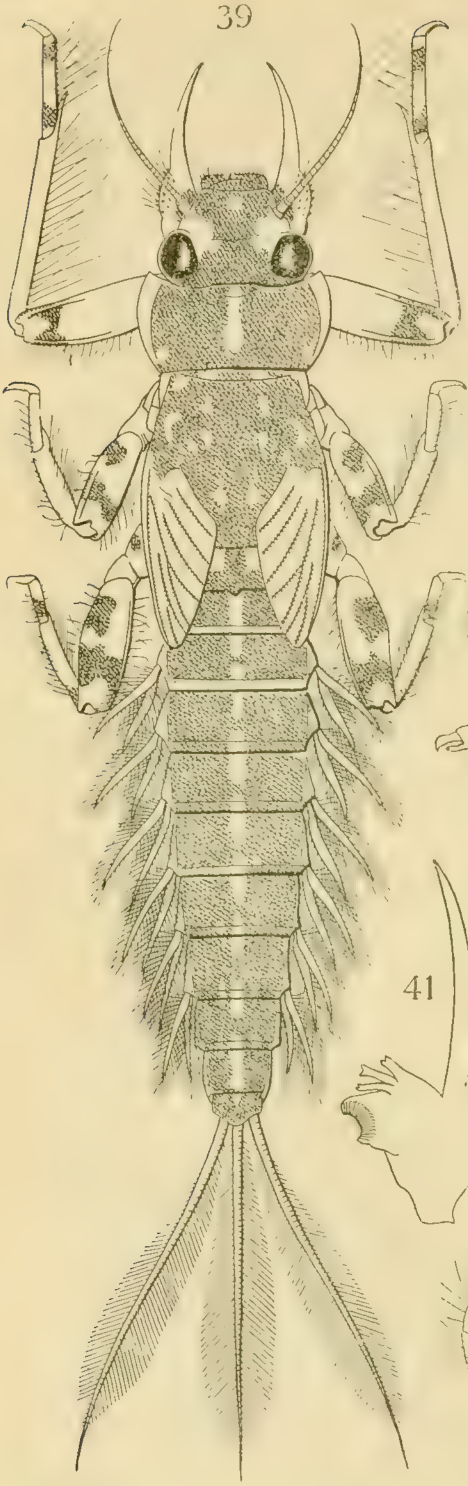

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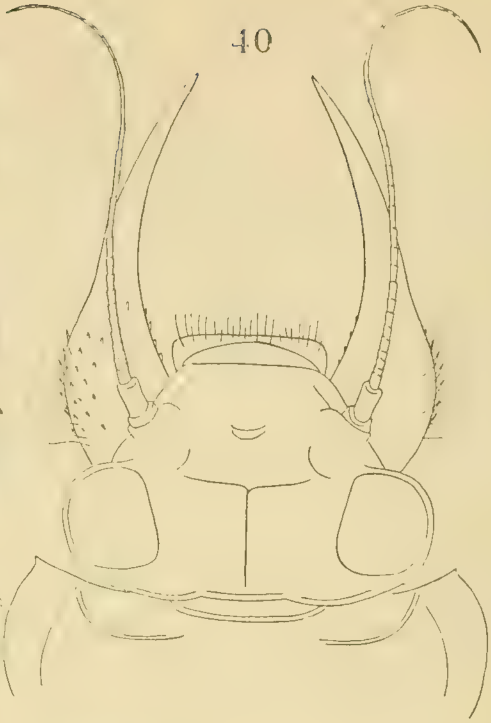

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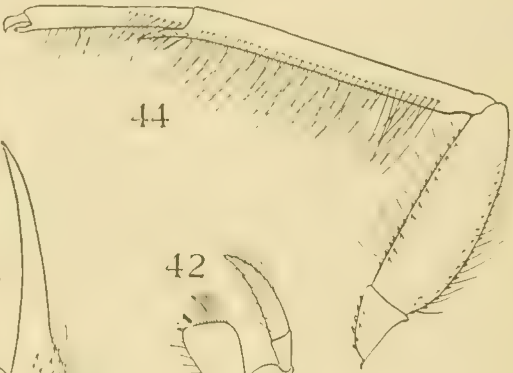

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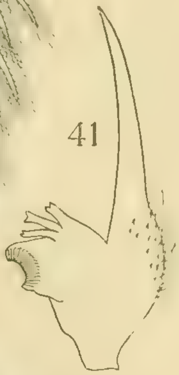

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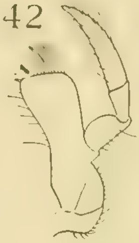

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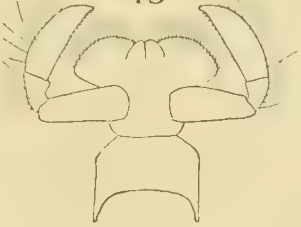

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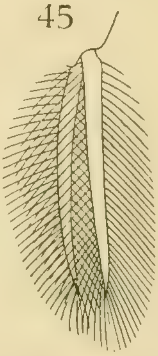

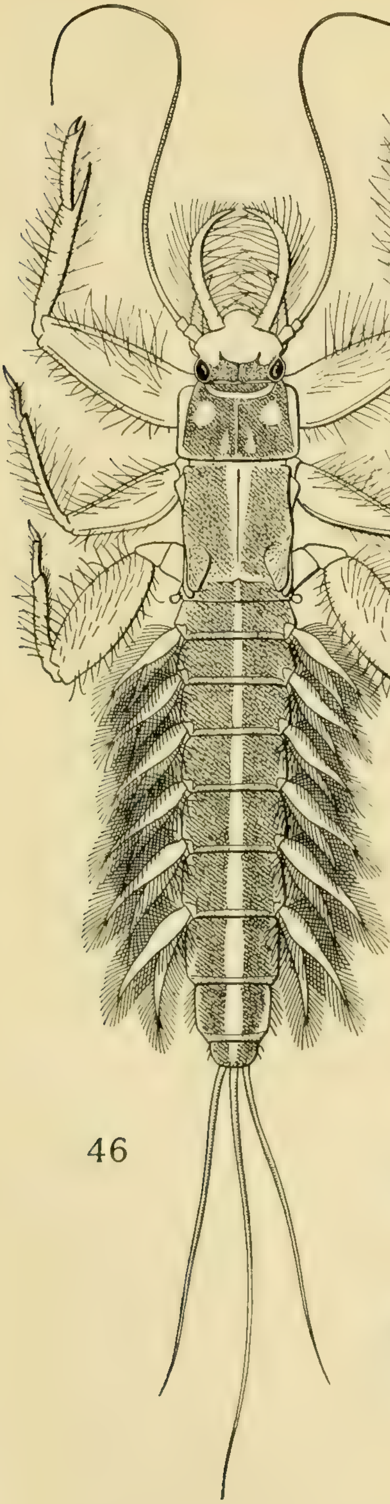

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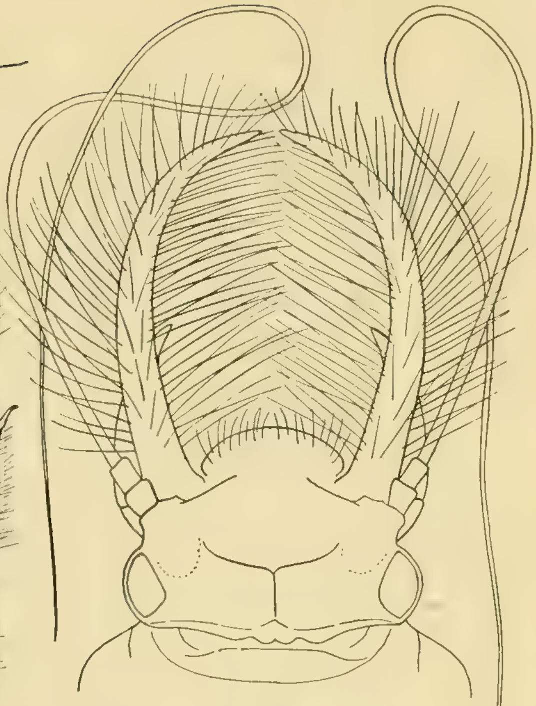

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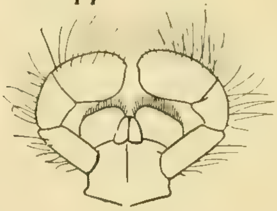

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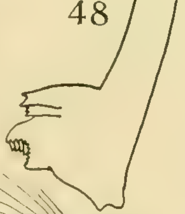

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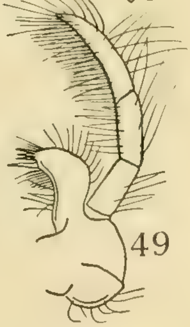

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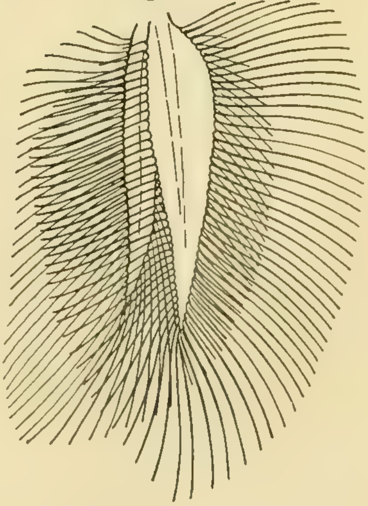

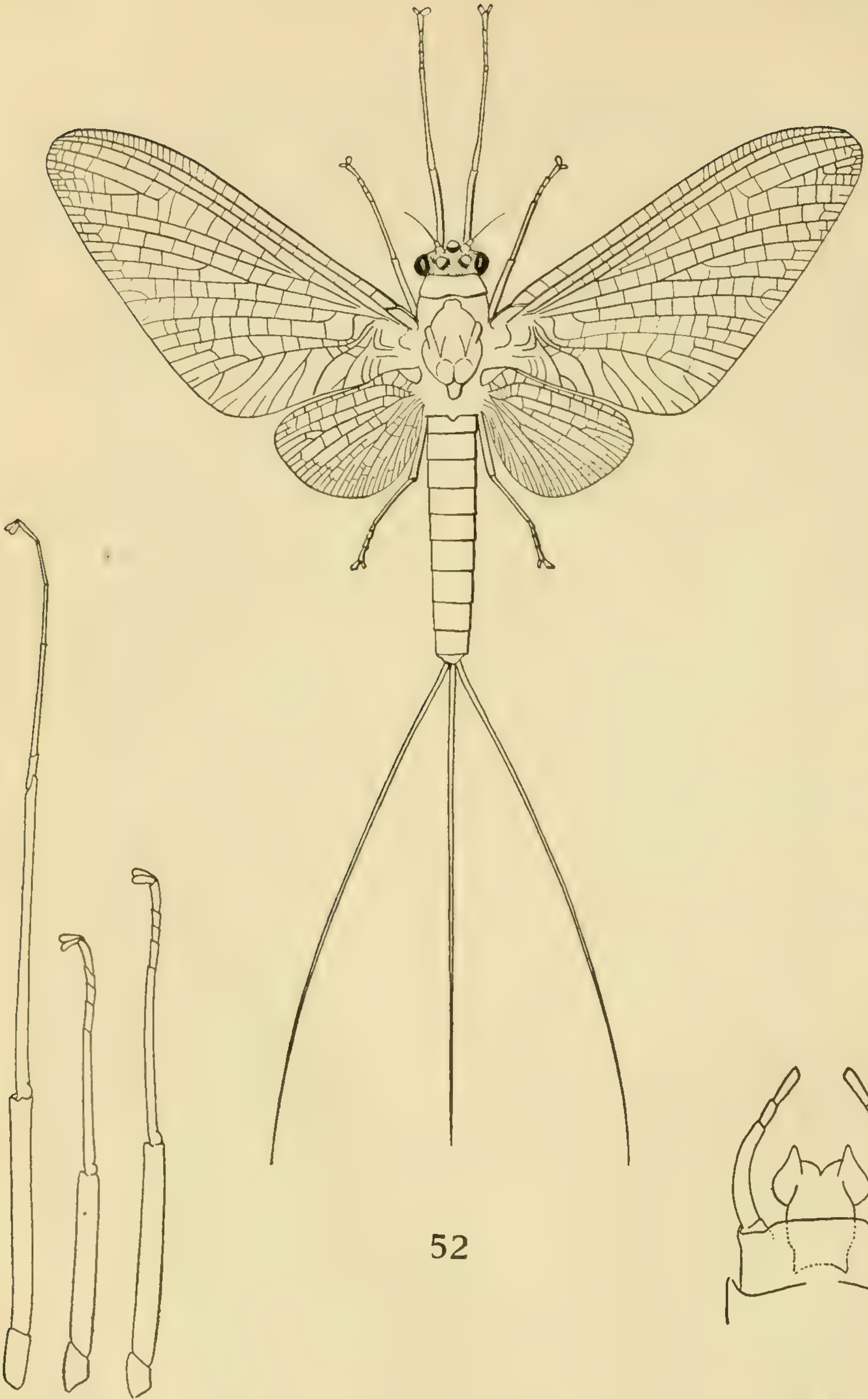

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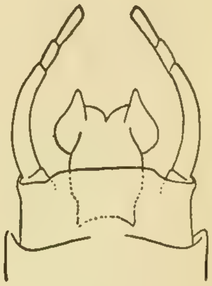

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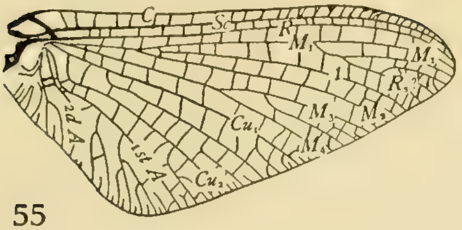
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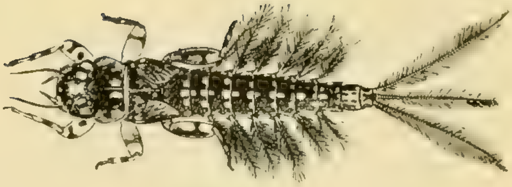

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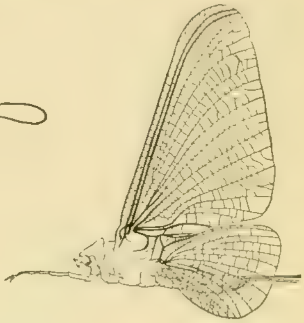

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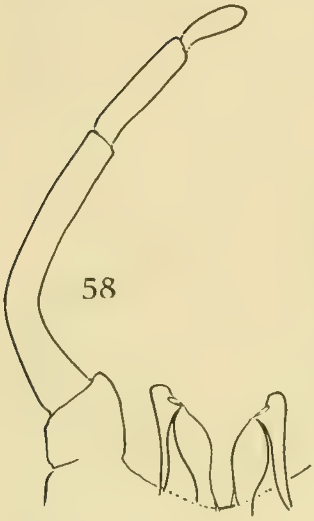

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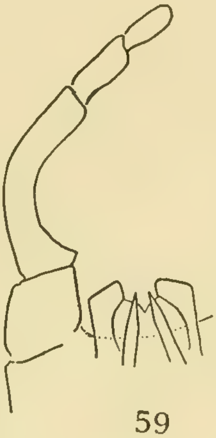

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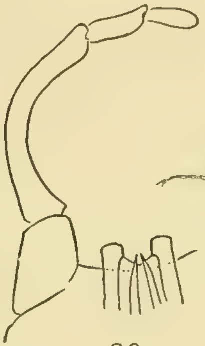

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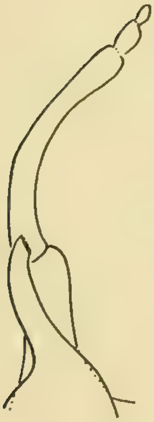

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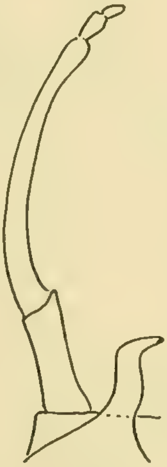

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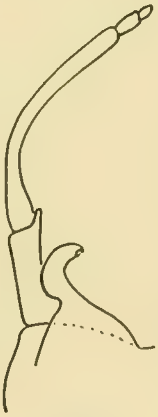

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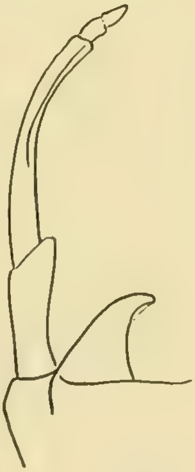

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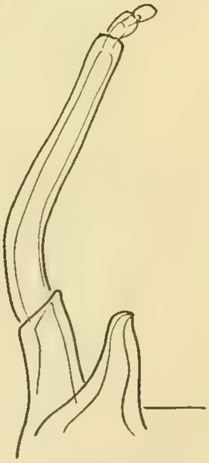

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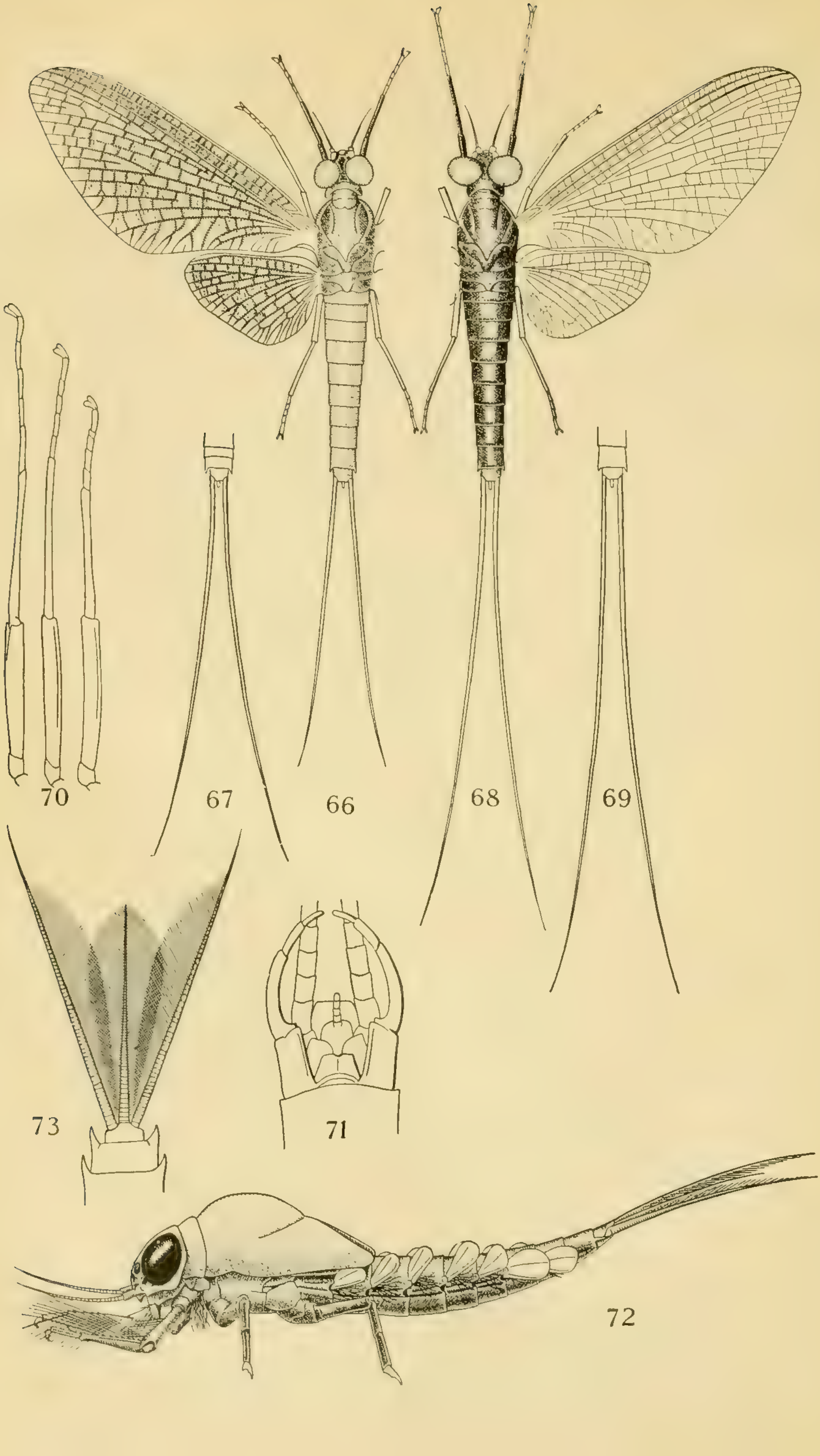
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HABITS OF YELLOW PERCH IN WISCONSIN LAKES

⁂

By A. S. Pearse
and
Henrietta Achtenberg

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⁂

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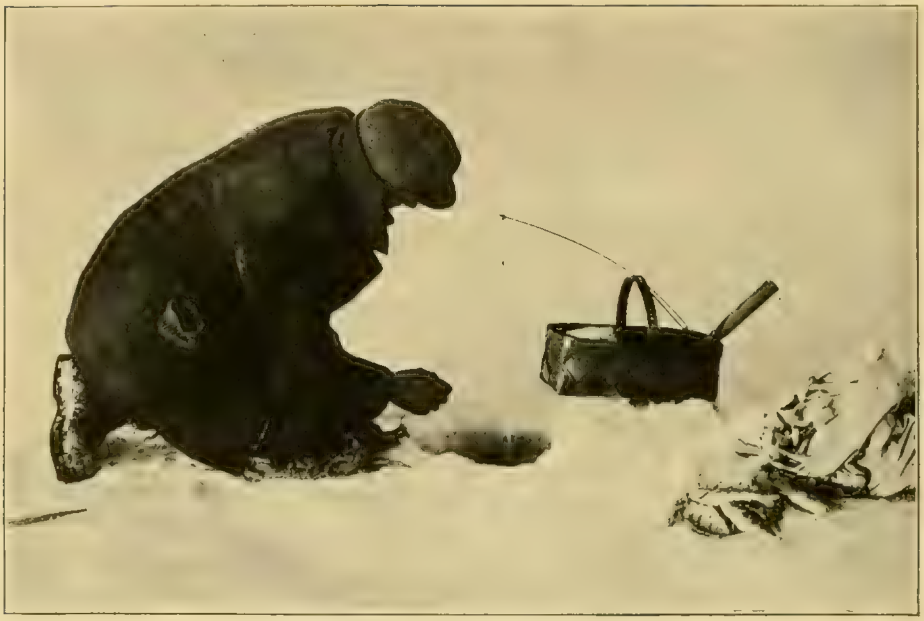

FIG. 1.—A fisherman on Lake Mendota. About 282,960 perch are caught through the ice each winter. (Photograph by L. W. Brown.)

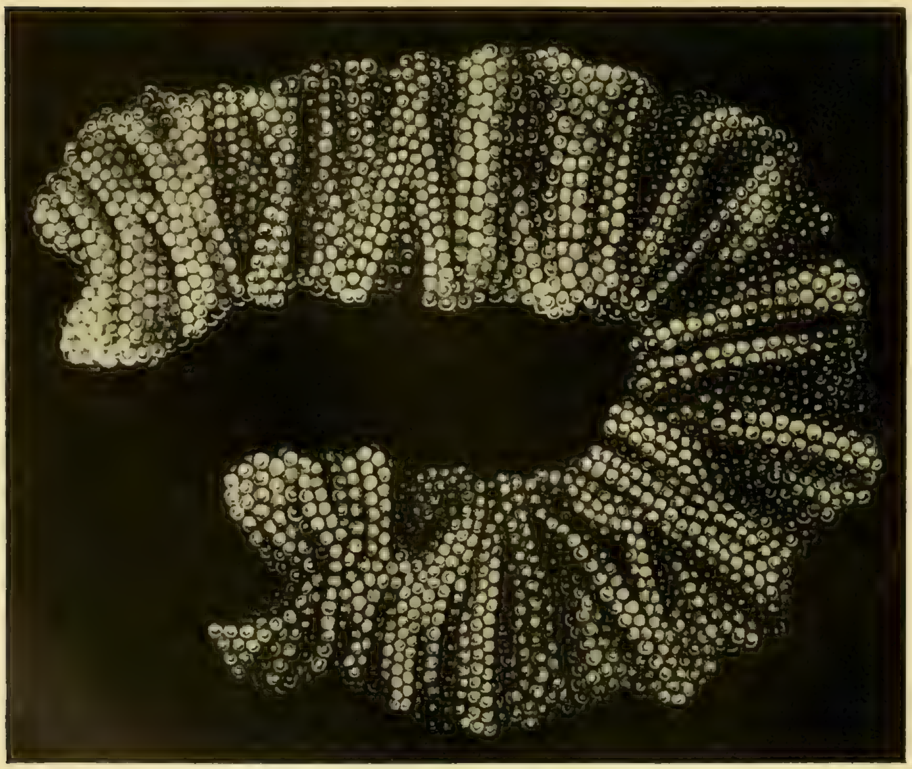

FIG. 2.—Egg string of perch. 37/61 reduction.

HABITS OF YELLOW PERCH IN WISCONSIN LAKES.

By A. S. PEARSE AND HENRIETTA ACHTENBERG.

INTRODUCTION.

The yellow perch, *Perca flavescens* (Mitchill), is widely distributed throughout the northeastern United States and southeastern Canada. "It is essentially a lake fish, but occurs also in running streams, most abundantly in the larger rivers and least so in creeks. * * * 'As a game fish the yellow perch can be commended chiefly on account of the fact that anybody can catch it. It can be taken with hook and line any month in the year and with any sort of bait—grasshoppers, angleworms, grubs, small minnows, pieces of mussel, or pieces of fish; and it will even rise, and freely, too, on occasion, to the artificial fly.' * * * It is easily taken through the ice in winter."[a] Systematically the perch is related to the pikes and the darters and, like them, is largely carnivorous in its feeding habits. It belongs to a family of "highly organized, shapely, powerful, and active fishes, thoroughly equipped for a predatory life, and filling an important place in the ecological system of our inland waters."[a]

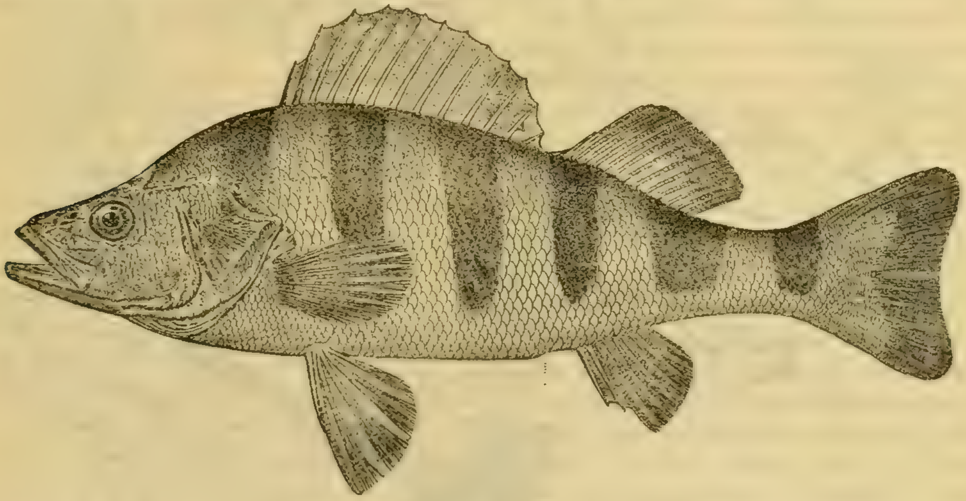

FIG. 1.—The yellow perch, *Perca flavescens* (Mitchill).

Wisconsin lakes in many localities furnish admirable habitats for perch, and those near Madison afford unusual opportunities for scientific study. The Wisconsin Geological and Natural History Survey has collected very complete data on the contour of the lake bottoms, the annual cycle of temperature changes, lake respiration, plankton, animal population of bottom, and other features which have direct application to the lakes as habitats for fish. Therefore, one who wishes to investigate fresh-water fishes in their natural surroundings can do so at Madison and know more about environmental conditions than anywhere else in America.

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[a] Forbes and Richardson, 1908, p. 277.

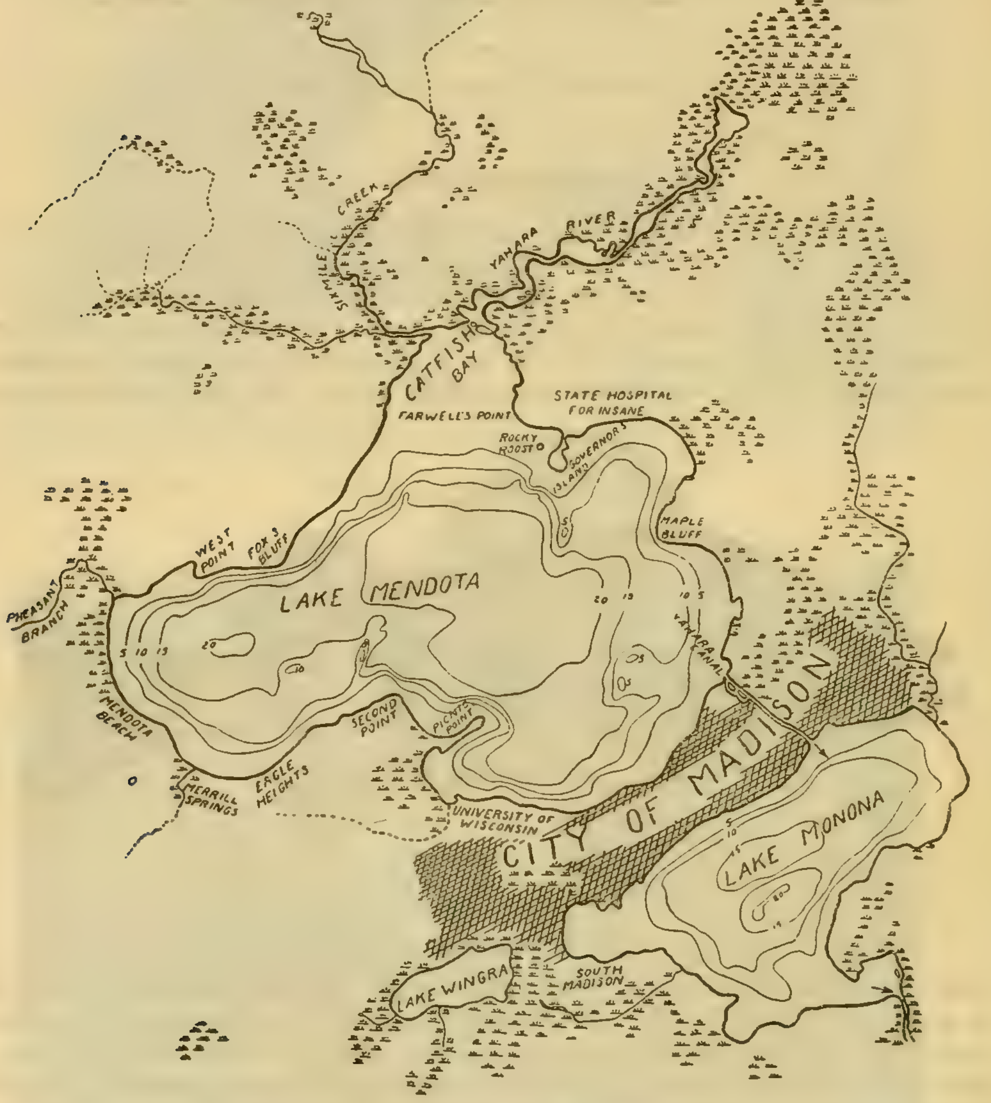
SIX MILE CREEK
YAHARA RIVER
CATFISH BAY
FARWELL'S POINT
STATE HOSPITAL FOR INSANE
ROCKY ROOST
GOVERNOR'S ISLAND
MAPLE BLUFF
WEST POINT
FOX'S BLUFF
PHEASANT BRANCH
LAKE MENDOTA
5 10 15 20
CANAL
MENDOTA BEACH
SECOND POINT
PICNIC POINT
MERRILL SPRINGS
EAGLE HEIGHTS
UNIVERSITY OF WISCONSIN
CITY OF MADISON
LAKE MONONA
LAKE WINGRA
SOUTH MADISON

Fig. 2.—Lake Mendota and Lake Wingra, the two lakes near Madison, Wis., in which the yellow perch was chiefly studied. [For dimensions see Table 1.]

Two of the Madison lakes (fig. 2), differing as much as possible, have been utilized for perch studies. Though both of these are of glacial origin, one is large and deep, with comparatively cool waters that become stratified thermally during the summer; the other is small, shallow, has wide seasonal variations in temperature, and shows no thermal stratification during the warmer months. The two lakes are compared in Table 1.

The greatest difference of biological importance between the two lakes is probably the thermal stratification, which is characteristic of Lake Mendota during the warmer months, but which is lacking in Lake Wingra. Birge and Juday (1911) have made complete records of the seasonal changes in Lake Mendota for several years. The lake is frozen over from three to nearly five months.[a] During this period there is little difference (0 to 2.5° C.) in temperature at different depths, and there is practically no circulation; the oxygen in the deepest parts becomes gradually exhausted, and the carbon dioxide increases. Soon after the ice goes out in the spring the lake begins to circulate freely from top to bottom. The temperature and dissolved gases therefore become uniform at all depths and so continue until the temperature reaches 4° C. The water near the surface then gradually grows warmer. About the end of June a thermocline, or stratum of rapid temperature change, is established, and after that there is no mixing between the water in the upper part of the lake and that in the deeper portions. When the stratification is complete, the lower, cooler water is cut off from contact with the atmosphere, and its oxygen is gradually used up. The plankton organisms leave it, but many of the insect larvæ, molluscs, and other animals which live on or in the soft bottom mud remain in the stagnant water (Juday, 1908). The upper stratum circulates throughout the summer and, therefore, has abundant oxygen; it also grows warmer and may reach a temperature of 25° C. or more. The thermocline is usually established at a depth of about 10 m. and moves deeper as the upper stratum of warm water grows thicker in late summer. In the autumn the upper water gradually grows cooler, and, finally, about the first of October, the "autumnal overturn" takes place—the lake circulates again throughout; gases and temperatures are again uniform at all depths. This condition continues until the lake again freezes.

Lake Mendota is, then, subject to two periods of stagnation. During the winter the water is all cold, and the deepest regions may be without oxygen; during the late summer and early autumn the lake is separated into three strata, a warm circulating stratum on top, a thin middle region of rapid transition in temperature and dissolved gases, and a lower, cool, stagnant region which is without oxygen and contains considerable carbon dioxide for about three months. During the spring and the autumn overturns all parts of the lake have the same temperature and the same dissolved gases.

Lake Wingra is, of course, subject to the same external seasonal changes as Lake Mendota but does not respond in the same way. It is so shallow that the water circulates freely from top to bottom while it is not covered with ice. Its shallow basin and small total body of water make it more susceptible to short periods of changes in temperature. It warms up more rapidly in the spring and cools more quickly in the autumn than Lake Mendota.

This brief summary gives some idea of the great contrasts between the two lakes, and there are, of course, many other minor differences. However, perch are the most abundant fish in both. The point which first attracted the attention of the writers was the fact that the perch in Lake Mendota are generally a third larger than those from Lake Wingra. Furthermore, in Lake Monona,[b] which receives the water discharged from Lake Mendota, they are still larger. The questions to which answers have been sought may be formulated somewhat as follows: (1) Why are perch the most abundant fishes in these lakes? (2) Why are the perch in Lake Mendota larger than those in Lake Wingra, and why do the fish of many lakes attain a certain maximum size? (3) What effect does the stagnation of a lake like Mendota have on the activities of the fishes in it? In seeking answers to these questions we were led to make routine examinations of perch of all ages from each lake and for every week in the year; to study the migration and distribution of perch in relation to the dissolved gases in the water and to determine the gaseous content of the swim bladders; to ascertain the amount of food eaten by perch and the rate of digestion; and to investigate the breeding, enemies, and other factors which might influence the life cycle of the perch in these lakes.

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[a] The earliest freezing over recorded since 1851 was Nov. 23; the latest, Jan. 14; corresponding dates for opening in the spring were Mar. 8 and May 4.

[b] Lake Monona has not been investigated to any extent by the writers.

During the investigation the authors were under continual obligation to the Wisconsin Geological and Natural History Survey and to the University of Wisconsin for the loan of apparatus and for assistance in other ways. Chancey Juday, in particular, gave many valuable suggestions and read the manuscript for this paper. A. R. Cahn and Dr. John Lowe furnished perch from other Wisconsin lakes for comparison and otherwise took a helpful interest in the work. Dr. R. A. Muttkowski identified the greater part of the insect remains found in the food. Miss Hattie J. Wakeman drew all the figures, with the exception of figure 1.

A few technical matters ought to be mentioned before taking up the habits of the perch. All lengths in this paper are given in millimeters and refer to the distance from the extreme anterior end to the beginning of the membranous portion of the caudal fin. Figures giving estimates of food, except where statement is made to the contrary, mean percentages by volume; + indicates an amount too small to be given a percentage value.

FOOD.

The yellow perch is more versatile in its feeding habits than its near relatives. The pikes are largely piscivorous, and the darters feed for the most part on insect larvæ, but the perch is equipped to secure almost anything edible. Its shape and structures for the capture of food are less specialized than those of other members of the family Percidæ, and it is correspondingly more versatile. The stocky body is suited to all sorts of situations; the sharp, backwardly directed teeth hold struggling animals; the slender gill rakers readily strain microscopic organisms from the water; and the activity of the swim bladder renders adjustment to various pressures comparatively easy, so that food may be sought at all depths. A perch may grub out insect larvæ from soft bottom mud, snatch crayfishes from their hiding places among the rocks alongshore, strain plankton animals from the open waters of lakes, lurk in the shore vegetation in order to capture passing fishes, or pull aquatic insects from their retreats among water plants.

Available food for perch is abundant in the two lakes investigated. Birge (1897) has shown that there may be at times more than 3,000,000 microscopic Crustacea per square meter of surface in the waters of Lake Mendota. Recent and as yet unpublished work by Birge and Juday has demonstrated the presence of more than 30,000 dipterous larvæ per square meter on the bottom of this lake, in addition to many other animals. Muttkowski (1918) counted the animals in typical habitats along the shores and computed the total numbers for the lake. He estimates that there are about 553,220,000 flatworms, 18,680,000 roundworms, 8,690,530,000 oligochætes, 103,200,000 leeches, 2,389,740,000 mollusks, 2,221,300,000 macroscopic crustaceans, 815,930,000 water mites, and 5,134,190,000 insect larvæ and adults in the shallow waters of Lake Mendota.

Aside from the myriads of pelagic animals and small fishes which may serve as food for perch, there are, then, 19,926,790,000 macroscopic animals along the shore. Though no careful studies of Lake Wingra have been made, its swampy shores and muddy, plant-covered bottom must support an equally abundant fauna suitable for perch food.

In order to determine what the perch eat in the two lakes selected for study, an attempt was made to examine 10 individuals each week for an entire year. This was easily accomplished in Lake Mendota during 1915, and many supplementary examinations were made throughout the following year. In Lake Wingra weekly examinations were made during the spring and summer, but in late autumn and winter perch could not always be caught regularly. While the lakes were free from ice, most of the perch were caught in gill nets and were therefore of fairly uniform size, because the dimensions of the mesh selected certain classes. The current opinion among fishermen that perch are uniformly larger in Lake Mendota than in Lake Wingra was proven by the gill-net catches to be correct (Tables 2 to 5; figs. 3 to 5). In the former lake more perch were caught per hour in 1-inch mesh nets than in those of three-fourths-inch mesh; and in the latter the opposite was true. During the winter months perch were caught through the ice on hooks baited with minnows or perch eyes. At the beginning of the work in Lake Mendota most of the fishing was done east of Picnic Point, but after June 25, 1915, the routine catches recorded in Tables 2 and 3 were made directly north of the University of Wisconsin. Catches were made in all parts of Lake Wingra.

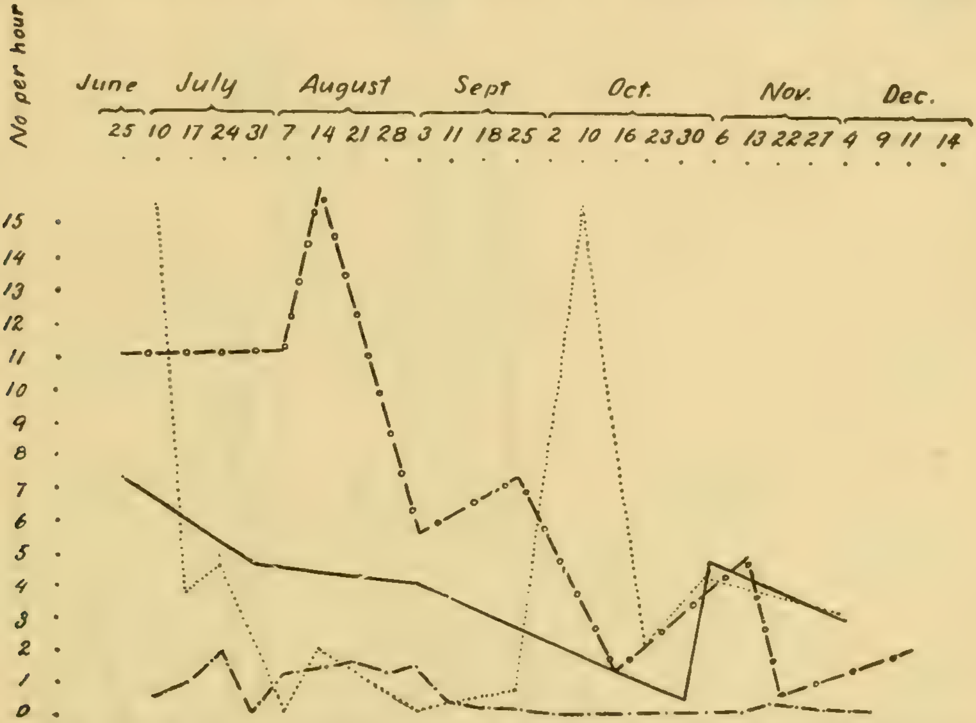


FIG. 3.—Perch caught per hour at various depths in 1-inch mesh gill nets, 3 by 75 feet, left in the water for approximately 24 hours, Lake Mendota, 1915. -.-.-.-, 0 to 5 m.; ———, 5 to 10 m.; -o-o-o-, 10 to 15 m.; . . . . . ., 15 to 24 m.

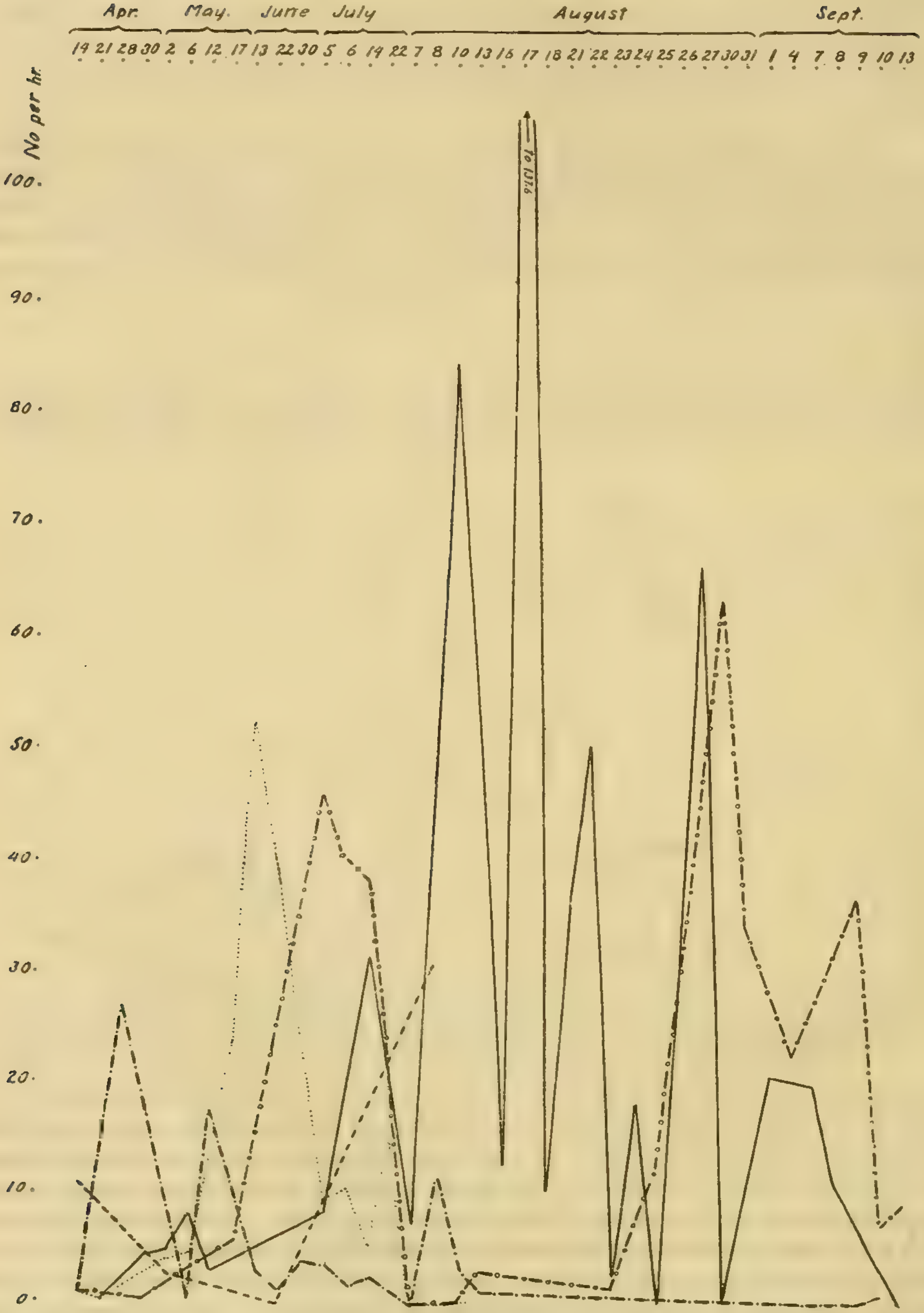


FIG. 4.—Perch caught per hour at various depths in ¾-inch mesh gill nets, 3 by 75 feet, and in 1-inch mesh gill nets, 3 by 60 feet, Lake Mendota, 1916. - - - - - - -, ¾-inch mesh net at 0 to 5 m.; -.-.-.-.-, 1-inch mesh at 0 to 5 m.; ———, 1-inch mesh at 5 to 10 m.; -o-o-o-o, 1-inch mesh at 10 to 15 m.; . . . . . ., 1-inch mesh at 15 to 20 m.

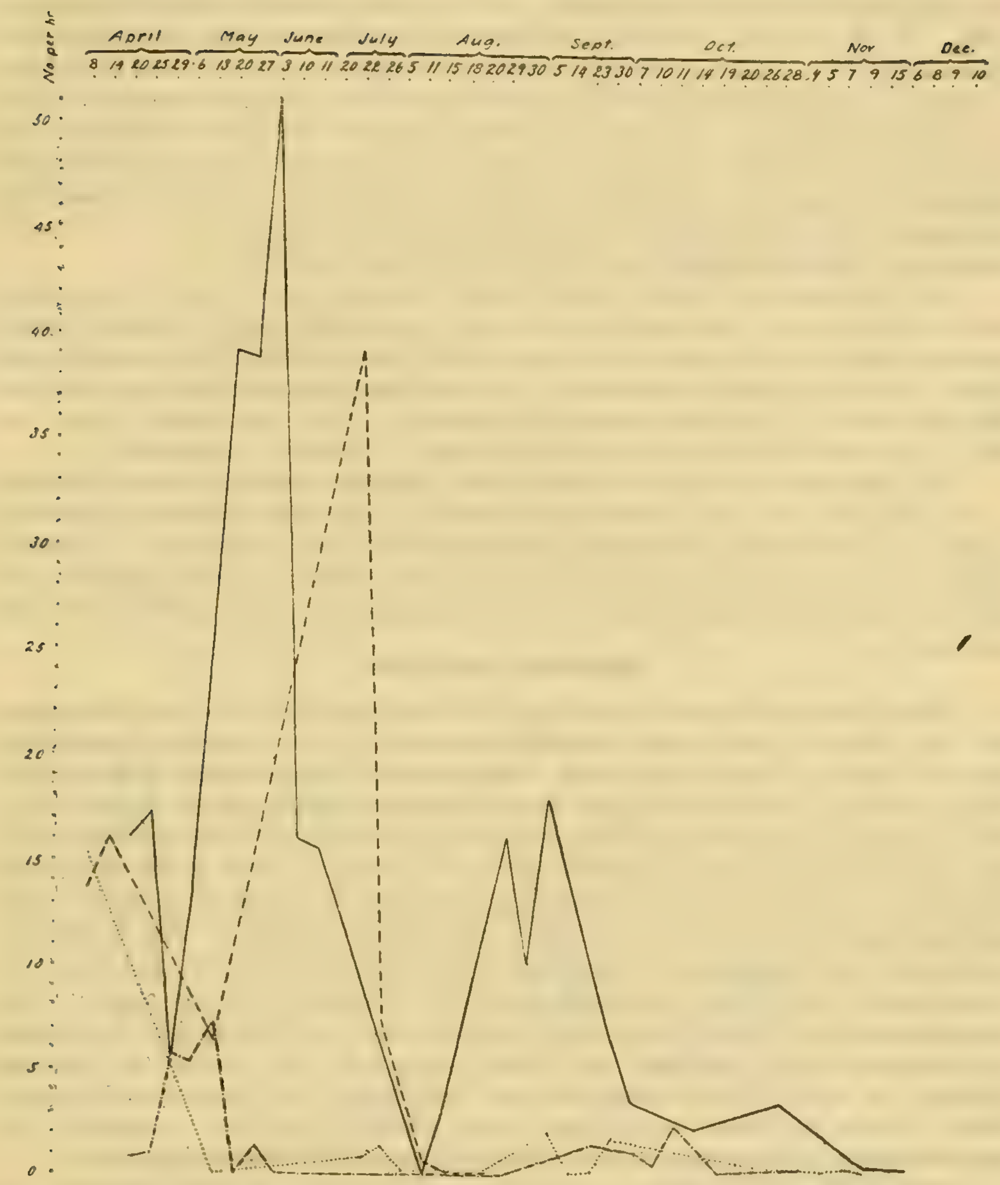


FIG. 5.—Perch caught per hour at various depths in ¾-inch mesh gill nets, 3 by 75 feet, and in 1-inch mesh gill nets, 3 by 60 feet, Lake Wingra, 1916. ———, ¾-inch mesh net at ¾ to 2 m.; - - - - - -, ¾-inch mesh at 2 to 3.5 m.; -.-.-.-.-, 1-inch mesh at ¾ to 2 m.; . . . . . ., 1-inch mesh at 2 to 3.5 m.

QUALITATIVE AND QUANTITATIVE FOOD DETERMINATIONS.

Perch were usually examined while fresh, but in a few instances they were preserved in 95 per cent alcohol before examination, as in the case of those collected in Oconomowoc Lake. In the laboratory the contents were stripped from the alimentary canal on a microscopic slide. A little water was added to the mass; it was then teased apart under a binocular microscope and after being well spread out was again examined with a compound microscope. The volume of all constituents of the food was estimated and recorded in percentages. As a rule, the larger constituents were counted, and in many instances the number of microscopic animals was also noted. It was not practicable to measure the volume of the food, because it was mixed with more or less mucous secretion, so that in the intestine it formed a cylindrical "string."

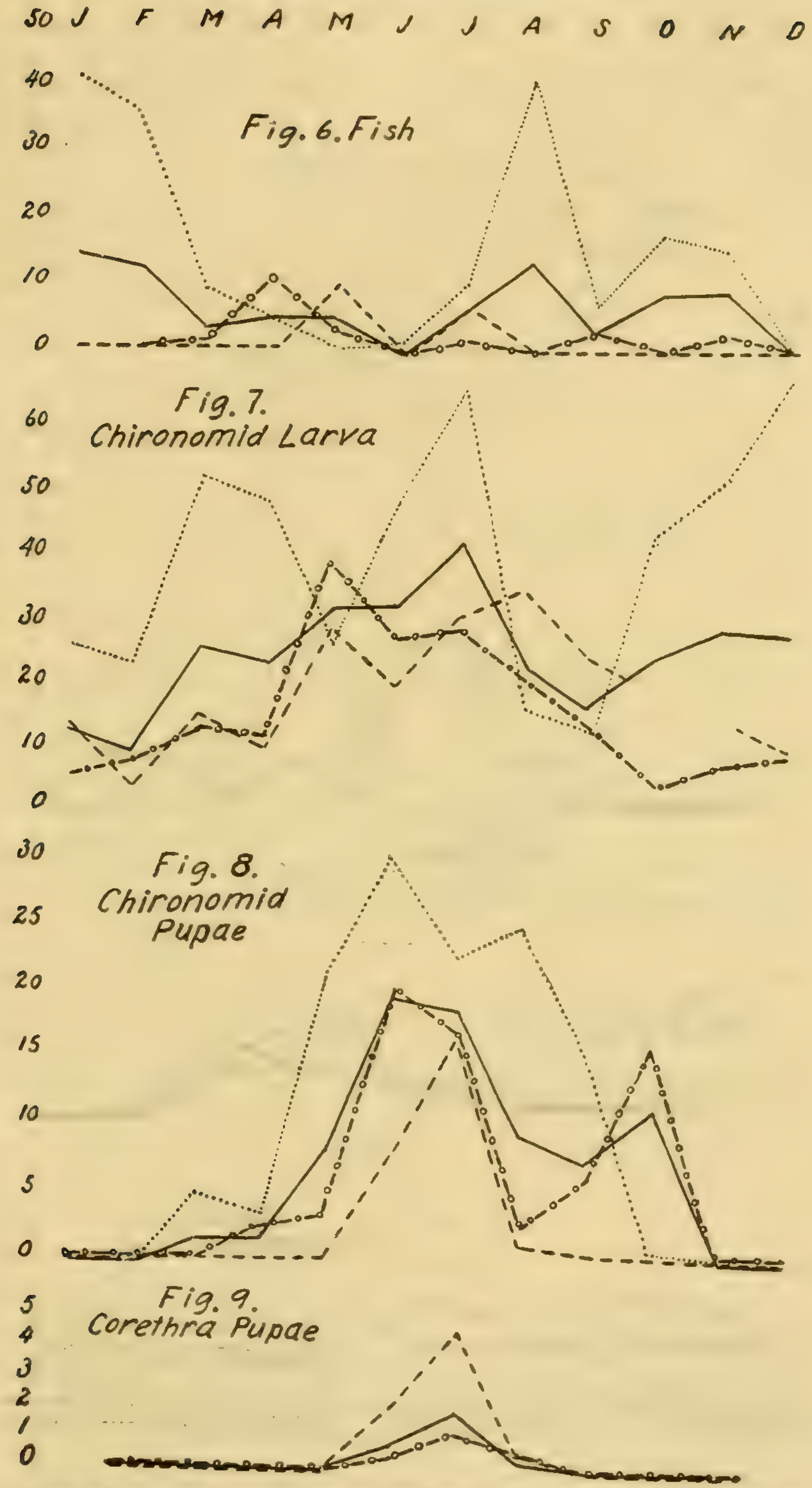
The total number of adult perch for which we made such volumetric percentage food estimates in the lakes studied was 1,147. Considering together those of various localities, habitats, and ages, the food, as a whole, was made up of 38.3 per cent insect larvæ, 21.4 per cent entomostracans, 9.5 per cent insect pupæ and adults, 6.1 per cent silt and débris, 5.5 per cent macroscopic Crustacea, 5.5 per cent plants, 4.5 per cent fish, 2.4 per cent molluscs, 1.4 per cent oligochætes, + leeches, + arachnids.

The maximum amount and number of the particular species of animals observed in the food have also been recorded, and a number of important examples are given in Table 10. No particular discussion of the different items in the food is necessary. Tables 6 to 9 show that entomostracans and insect larvæ are most important; but there is also a good representation of other animals, plants, and mud from the lake bottom.

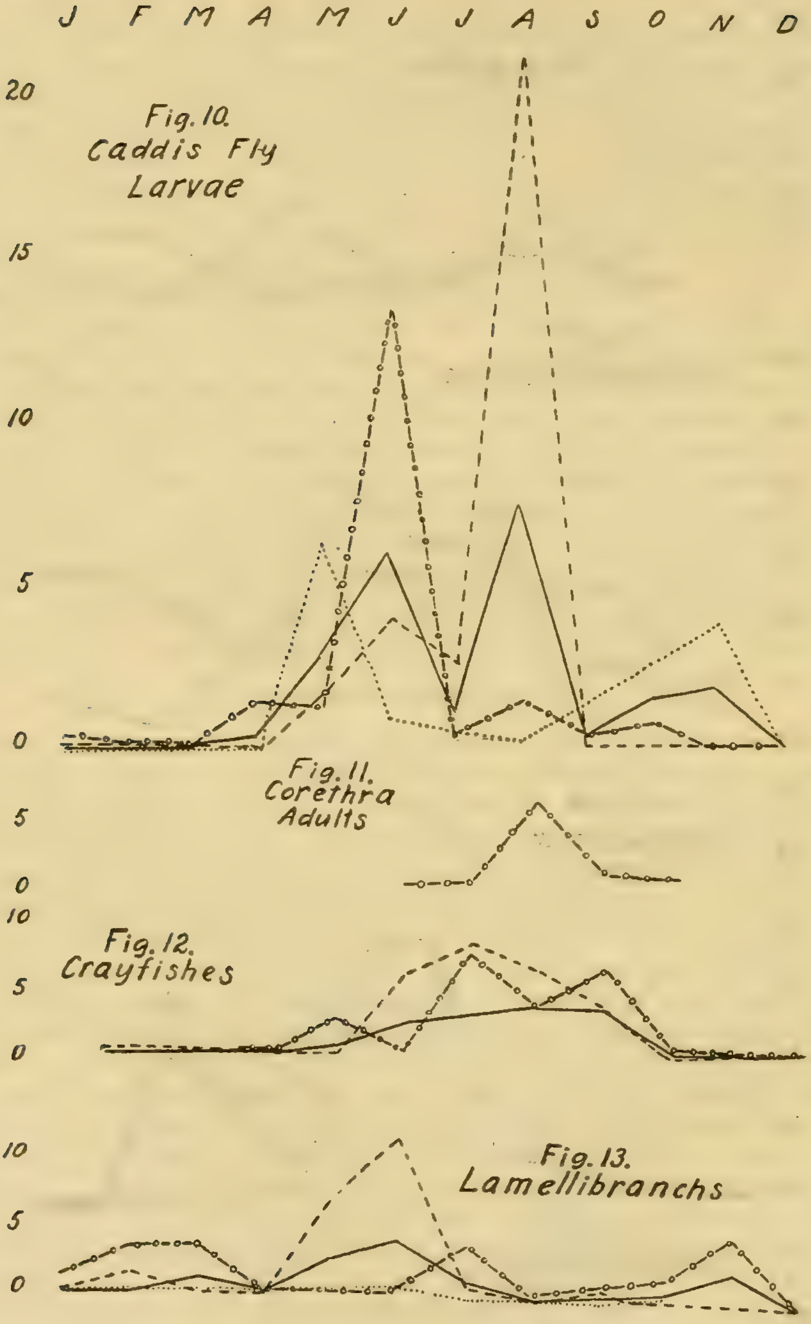
SEASONAL VARIATION.

Though the diet of perch is made up of the same general kinds of food throughout the year, there is considerable seasonal variation in all the important constituents, some of which are eaten only during certain months. The seasonal appearance of various items as constituents of perch food is represented graphically in figures 6 to 30, the curves showing the fluctuations in each throughout the year. From a study of these the annual food cycle may be outlined somewhat as follows: Perch at all seasons feed largely on or near the bottom. During the spring they come inshore, probably chiefly for breeding, and feed more or less among the aquatic vegetation. This is indicated by the rise in the percentages of plants, gastropods, Corethra larvæ, silt, and fine débris in the food at that time. In summer perch leave the deep water on account of its stagnation and feed on the bottom near the thermocline, as is indicated by the increase of chironomid larvæ, crayfishes, and midge pupæ in the diet. After the autumnal overturn the perch return to deep water and feed largely on Cladocera and Corethra larvæ. During the winter they remain in the depths of the lake, as shown by the preponderance of cladocerans, silt and débris, chironomid larvæ, and Sialis larvæ.

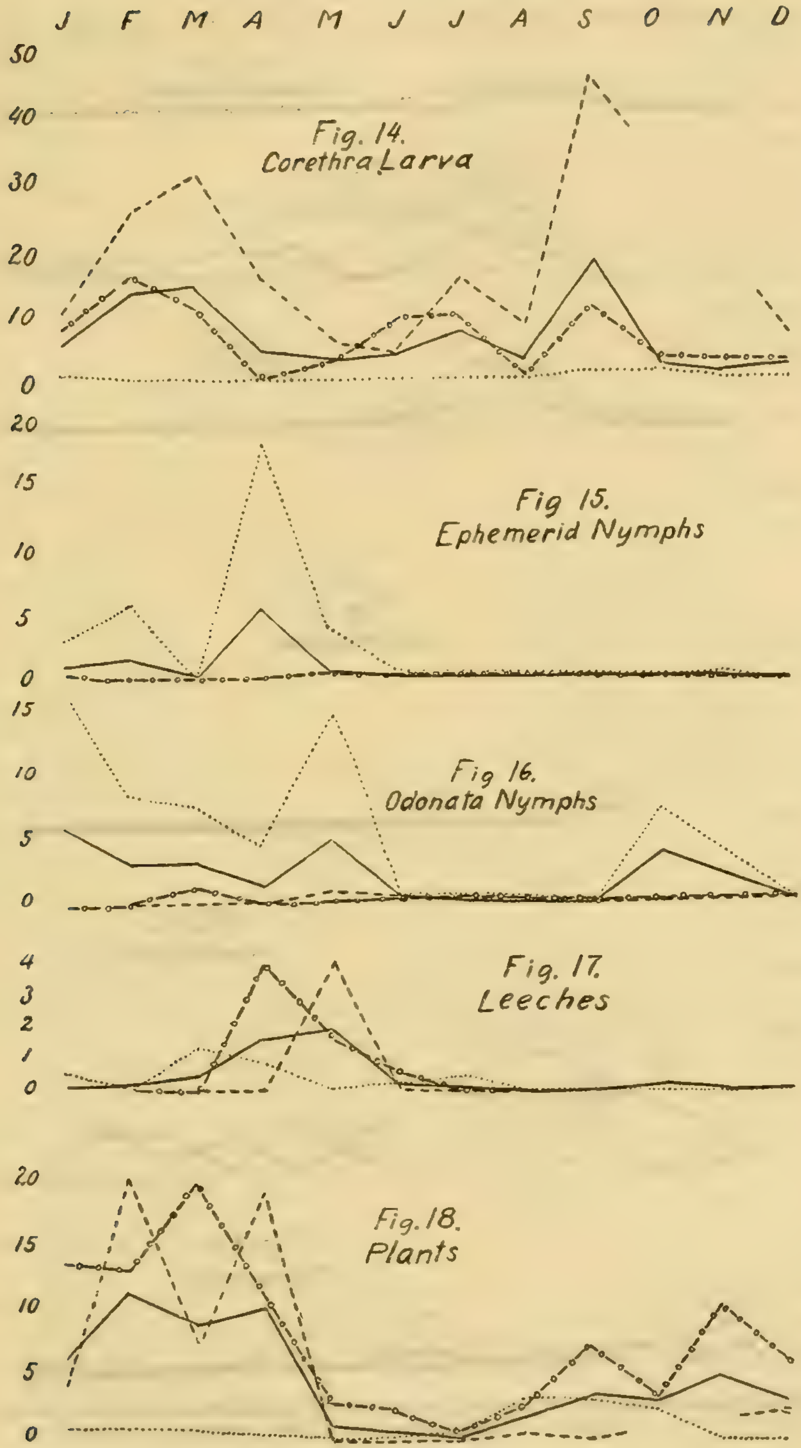
Some foods (like Corethra and chironomid adults, crayfishes, Corethra and chironomid pupæ, mites, and ostracods) were eaten only during the warmer months; some (copepods, oligochætes, algæ) were eaten throughout the year in small quantities; other foods (Corethra larvæ, chironomid larvæ, Cladocera, silt and débris, Sialis larvæ, etc.) appeared at all seasons but showed rather striking maxima during certain months. The time at which a particular food was taken in greatest quantity often coincided with



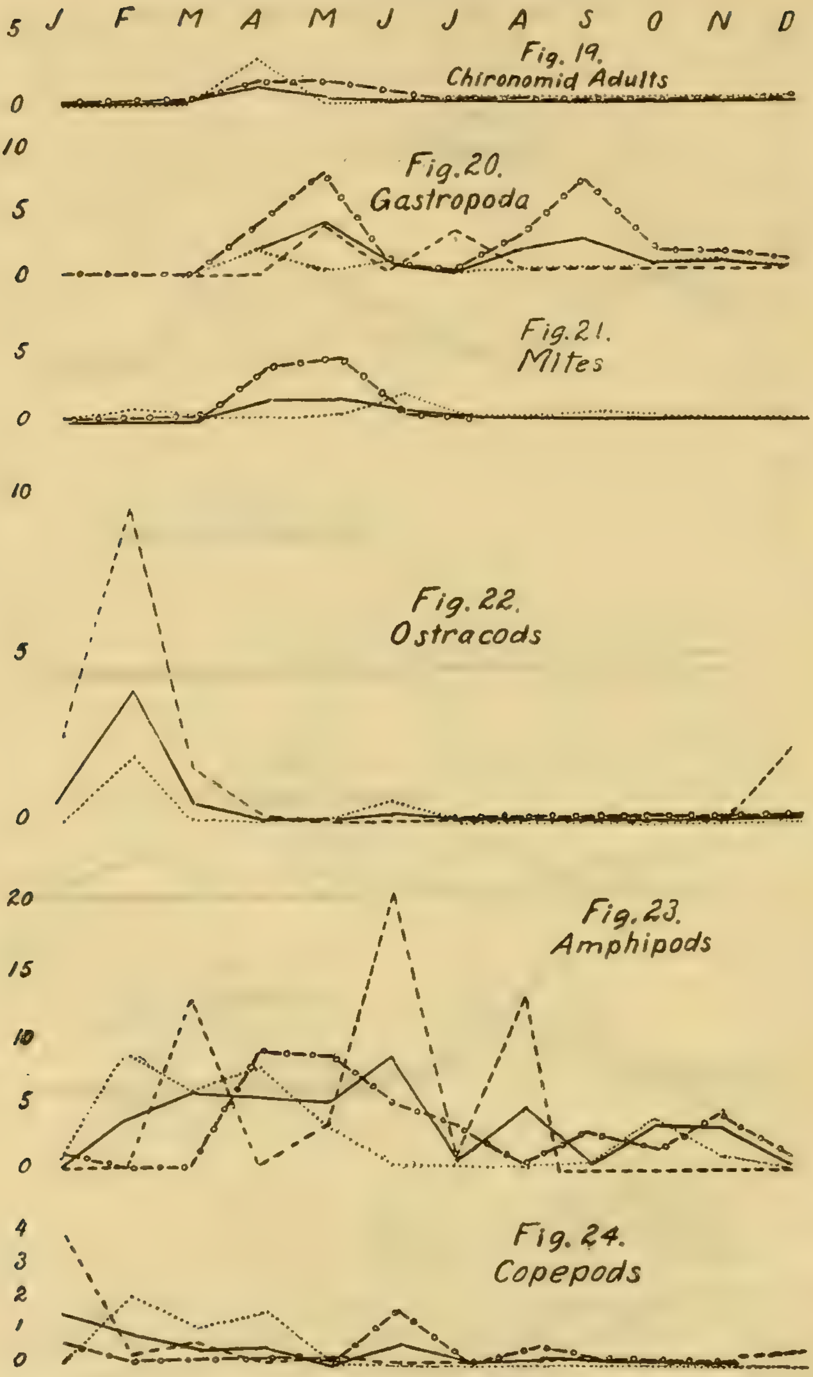
FIGS. 6 TO 9.—Percentage by volume of four constituents of perch food which increased markedly in the summer. -o-o-o-, Lake Mendota, 1915; - - - - - -, Lake Mendota, 1916; . . . . . ., Lake Wingra, 1916–17; ———, average.



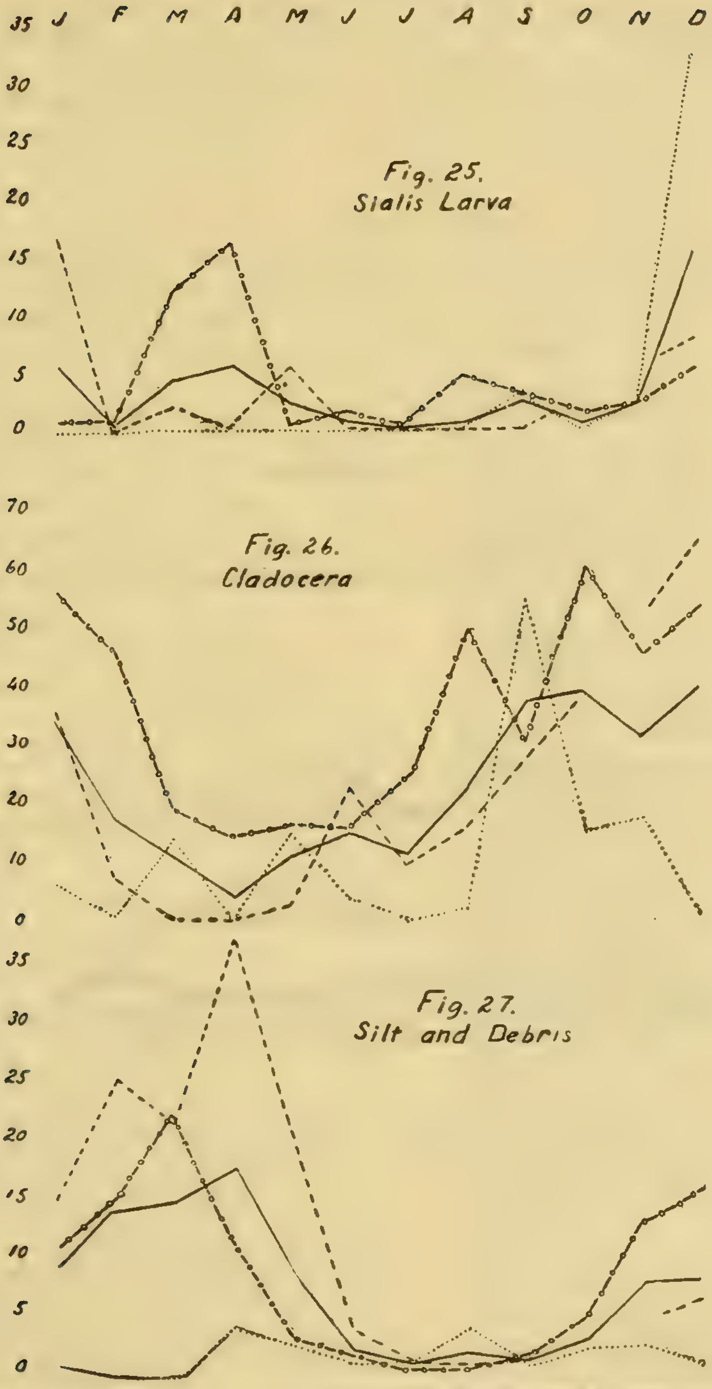
FIGS. 10 to 13.—Percentage by volume of four constituents of perch food which increased markedly during the summer. -o-o-o-, Lake Mendota, 1915; - - - - - -, Lake Mendota, 1916; . . . . . ., Lake Wingra, 1916–17; ———, average.



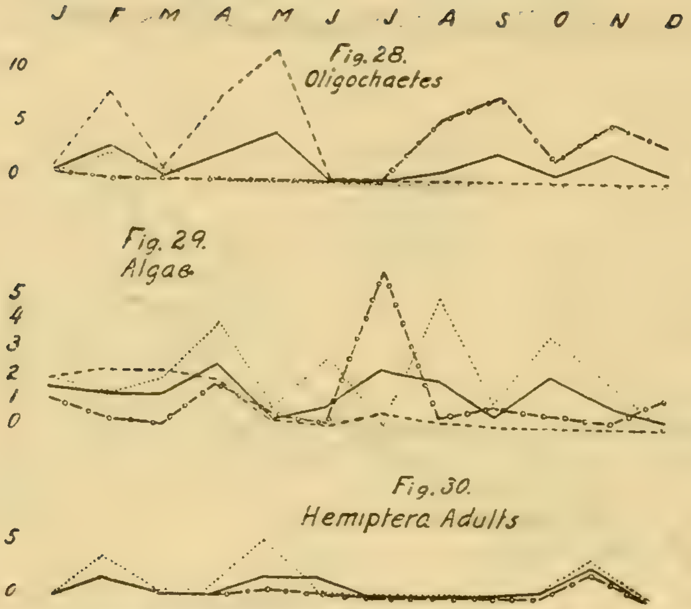
FIGS. 14 to 18.—Percentage by volume of five constituents of perch food which increased markedly during the spring or autumn. -o-o-o-, Lake Mendota, 1915;, - - - - - -, Lake Mendota, 1916; . . . . . ., Lake Wingra, 1916–17; ———, average.



FIGS. 19 to 24.—Percentage by volume of six constituents of perch food. -o-o-o-, Lake Mendota, 1915; - - - - - -, Lake Mendota 1916; . . . . . ., Lake Wingra, 1916–17; ———, average.



FIGS. 25 to 27.—Percentage by volume of three constituents of perch food which increased in amount in the winter. -o-o-o-, Lake Mendota, 1915; - - - - - -, Lake Mendota, 1916; . . . . . ., Lake Wingra, 1916–17; ———, average.



FIGS. 28 to 30.—Percentage by volume of three constituents of perch food. o-o-o-, Lake Mendota, 1915; - - - - - -, Lake Mendota, 1916; . . . . . ., Lake Wingra, 1916–17; ———, average.

its period of greatest abundance (adult midges, midge pupæ), but in other cases there was no such correlation. In the autumn the number of cladocerans in Lake Mendota increased (Birge, 1897), and the quantity eaten by perch also increased, but during the vernal cladoceran increase the opposite was true. Although copepods rivaled cladocerans in abundance at certain seasons they were never eaten in large quantities, probably because they are active, small, and do not collect in swarms to any extent, as cladocerans do.

The following list gives the number of perch out of the 1,147 examined which ate each constituent of the food; the percentage of the total which each constituent formed when it was 1 per cent or more; and the occurrence of the constituents throughout the year. All figures in parentheses mean percentage of total food by volume; figures outside parentheses indicate the number of fish eating each food.

- Fish (4.5), all year:
  - Fish eggs—
    - Unidentified, 2, April.
    - Cisco eggs, 1, November.
    - Perch eggs, 4, April.
    - Sucker eggs, 4, May.
  - Fish remains—
    - Unidentified remains (3.9), 85, March to November.
    - Abramis chrysoleucas, 1, October.
    - Eucalia inconstans, 1, February.
    - Lepomis incisor, 6, January, February.
    - Notropis heterodon, 1, February.
- Insect larvæ (38.3), all year:
  - Diptera larvæ (32.7)—
    - Unidentified chironomid larvæ (5), 148, all year.
    - Chironomus abbreviatus, 10, May to September.
    - C. decorus (8.3), 288, all year.
    - C. fulviventris (1.7), 86, all year.
    - C. lobiferus, 62, all year.
    - C. modestus, 3, April.
    - C. tentans (2), 28, October to February.
    - C. viridicollis, 7, October, December.
    - C. viridis, 1, August.
    - C. sp. 82 Johannsen, 1, May.
    - C. sp. 83 Johannsen, 3, May.
    - Corethra punctipennis (5.6), 329, all year.
    - Cricotopus trifasciatus, 7, April, May.
    - Orthocladius sp., 3, July, March.
    - O. nivoriundus, 2, July.
    - Palpomyia longipennis, 6, May, July.
    - Probezzia glaber, 12, April to July.
    - Probezzia pallida, 14, April to July.
    - Procladius sp., 29, March.
    - Protenthes choreus (3), 166, all year.
    - P. culiciformis, 2, August.
    - Stratiomyia sp., 1, June.
    - Tanypus sp., 37, all year.

- Insect larvæ—Continued.
  - Diptera larvæ—Continued.
    - T. carneus, 7, April, May.
    - T. decoloratus, 6, April, May.
    - T. monilis, 20, July, November.
    - Tanytarsus dives, 15, March to May.
    - Tanytarsus sp., 2, March.
  - Ephemerid nymphs (1)—
    - Mayfly sp., 32, all year.
    - Bætisca sp., 22, March to May.
    - Cænis diminuta, 9, May to September.
    - Callibætis sp., 18, April to May.
    - Ecdyurus maculipennis, 1, June.
    - Ephemerid sp., 14, May, June.
    - Heptagenia interpunctata, 1, June.
    - Siphlurus sp., 1, May.
  - Odonata nymphs (1.4)—
    - Damselfly sp., 34, all year.
    - Argia sp., 1, May.
    - Enallagma antennatum, 19, May to July.
    - E. hageni, 28, March to July.
    - E. pollutum, 6, May.
    - Ischnura verticalis, 9, March to June.
    - Dragonfly sp., 7, November to July.
    - Anax junius, 2, March, July.
    - Libellula sp., 1, April.
    - Nehalenna irene, 1, April.
    - Sympetrum, 3, October.
  - Trichoptera larvæ (1.5)—
    - Agraylea multipunctata, 10, June, July.
    - Hydroptila, 3, June, August.
    - Leptocella uwarowii, 17, March to September.
    - Leptocerus sp., 5, June to November.
    - Leptocerus dilutus, 7, May, August.
    - Molanna uniophila, 5, July, August.
    - Orthotrichia, 1, October.
    - Platyphylax subfasciatus, 2, May, August.
  - Neuroptera larvæ (1.7)—
    - Sialis infumata (1.7), 75, all year.

- Insect larvæ—Continued.
  - Coleoptera larvæ—
    - Carabus, 1, July.
    - Parnid, 1, March.
    - Pelocaris femoratus, 1, June.
  - Hemiptera nymphs—
    - Plea minutissima, 1, July.
- Insect pupæ (8), all year:
  - Corethra punctipennis, 12, August, September.
  - Chironomus sp. (3), 128, all year.
  - C. decorus (3.5), 139, April to October
  - C. digitatus, 2, July.
  - C. fulviventris, 18, March to May.
  - C. lobiferus, 26, March to November.
  - C. viridis, 1, July.
  - Palpomyia sp., 4, August.
  - Probezzia glaber, 2, August, September.
  - P. pallida, 1, August.
  - Protenthes choreus, 22, April to June.
  - Tanypus sp., 7, June.
  - T. carneus, 4, May.
  - Tanytarsus dives, 13, March, April.
- Adult insects (1.5), all year:
  - Ammophila sp., 2, August, October.
  - Aphodius inquinatus, 2, April, May.
  - Brachonid sp., 1, July.
  - Camponotus, 1, May, August.
  - Carabid, 1, April.
  - Chironomus sp., 13, April to November.
  - C. plumosus, 2, April.
  - Corethra punctipennis, 7, July, August.
  - Collembolid, 1, July.
  - Corixa, 40, February to November.
  - Enchenopa binotata, 1, July.
  - Heterocerus sp., 1, April.
  - Lachnosterna, 1, May.
  - Noctuid sp., 1, July.
  - Platyphylas subfasciatus, 1, August.
  - Sawfly, 1, April.
  - Scarabæid, 1, April.
- Arachnida, February to September:
  - Arrhenurus, 7, May.
  - Atax turgidus, 2, June.
  - Limnesia, 15, May to July.
  - Mites, unidentified, 17, February to September.
  - Spider, 1, June.
- Amphipoda (4.3), all year:
  - Dikerogammarus fasciatus, 9, February to September.
  - Gammarus limnæus, 4, March.
  - Hyalella azteca (4.1), 232, all year.
- Isopoda: Asellus communis, 4, February, March.
- Decapoda, (1.2), May to August:
  - Cambarus propinquus, 8, May to July.
  - C. virilis, 1, July.
  - Crayfish, unidentified, 16, May to August.
- Entomostraca (21.4), all year:
  - Cladocera (20)—
    - Acroperus, 6, June, July.
    - Bosmina, 7, July.
    - Ceriodaphnia, 13, May to August.
    - Chydorus sphæricus, 29, February to October.
    - Daphnia longispina hyalina (9.8), 215, all year.
    - D. pulex (1.2), 42, June to December.
    - D. retrocurva, 8, September.
    - Diaphanosoma, 6, July, August.
    - Eurycercus lamellatus (1.2), 95, all year.
    - Leptodora, 135, all year.
    - Pleuroxus procurvatus, 5, July, January.
  - Copepoda (1.1), all year—
    - Canthocamptus, 1, June.
    - Cyclops albidus, 2, March.
    - C. bicuspidatus (1), 86, all year.
    - C. fuscus, 3, January.
    - C. leuckarti, 2, August.
    - C. viridis, 1, July.
    - Diaptomus, 1, July.
    - Nauplii, 2, June.
  - Ostracoda, 52, all year.
- Bryozoa:
  - Statoblast, 1, September.
  - Pectenella, 3, February, August.
- Mollusca (2.4), all year:
  - Amnicola, 13, June to November.
  - Campeloma, 10, May, June.
  - Corneocyclas, 24, May to June.
  - Limnæa, 2, June, October.
  - Physa heterostropha, 41, all year.
  - Planorbis, 12, January to October.
  - Snail eggs, 1, September.
  - Sphæridæ, 27, March to October.
  - Sphærium occidentale, 9, January to October.
  - Valvata tricarinata, 6, May.
- Oligochæta (1.4), February to September:
  - Limnodrilus, 53, February to September.
  - Tubifex, 2, June.
- Gordius, 23, December to July.
- Hirudinea, January to March:
  - Unidentified leech, 11, May, July.
  - Glossiphonia stagnalis, 4, January to March.
  - G. complanata, 2, June.
- Protozoa: Arcella, 1, April.

- Plants (5.5), all year:
  - Unidentified remains (4), 225, all year.
  - Algæ, all year—
    - Unidentified, 7, April to September.
    - Aphanothece, 19, April, September.
    - Chara, 2, March, April.
    - Closterium, 1, April.
    - Desmids, 1, April.
    - Diatoms, 20, October to March.
    - Filamentous algæ, 121, all year.
    - Gelatinous algæ, 4, July.
    - Hydrodiction, 1, July.
    - Protococcus, 5, January, April.
    - Rivularia, 3, October.
- Plants—Continued.
  - Algæ, all year—Continued.
    - Spirogyra, 1, November.
    - Tabellaria, 1, November.
  - Ceratophyllum, 1, January.
  - Elodea, 5, March, September.
  - Lemna, 8, May to December.
  - Plant leaves, 7, May to July.
  - Plant seeds, 12, May to March.
  - Potamogeton, 3, May to October.
  - Vallisneria, 1, October.
  - Wolffia, 2, June.
- $CaCO_3$ crystals, 17, February to April.[a]
- Silt and débris (6.1), 276, all year.

QUANTITY OF FOOD CONSUMED AND RATE OF DIGESTION.

After the constituents of perch food had been ascertained and their percentages by volume determined, it became necessary, in order to gain some idea of a perch's food requirements from day to day, to find out how much it could consume in a given time and how fast digestion progressed. With such purposes in mind, a medium-sized perch (weight, 48 g.; volume, 50 c. c.) was placed in a 5-gallon spherical glass aquarium and fed all it would eat from June 19 to July 20, 1916. The results of these experiments are shown in Table 13. Similar experiments were carried out later on smaller and larger fish and are in part summarized in Tables 11 to 15. The largest perch under observation were three individuals weighing about 247 g. and having volumes of about 250 c. c. They were tested from December 18, 1916 to January 23, 1917, and ate only a few Dikerogammarus, although they were offered the same foods as smaller fishes tested at the same time (Tables 12 and 14). This agrees with the observations of Knauthe (1907), who stated that large carp usually would not eat when the temperature was below 6 to 8° C.

As to the volume of the food in proportion to the bulk of the perch eating it, we have only a few observations. Table 13 shows that a perch displacing 50 c. c. of water ate the following percentages of its own volume per hour when given more than it consumed: Damselfly nymphs, 0.3 per cent; snails, 0; minnows, 0.46 per cent; earthworms, 0.32 per cent. On January 12, 1917, a perch having a volume of 2.1 c. c. ate a minnow (*Pimephales notatus*) which had a bulk of about 0.7 c. c. Reighard (1915, p. 237) gives instances where adult perch ate other individuals of their own species which were almost as large as themselves.

The tables show that the same foods were digested more rapidly by small than by large perch and that, when fish of similar size ate at different temperatures, digestion was slower at lower temperatures. To take a concrete illustration: A perch about 62 mm. long ate seven chironomid larvæ (having a volume of 0.3 c. c.) at 2.5° C. and digested them in 43.7 hours; the same individual at 16° C. ate 0.84 c. c. of chironomid larvæ and digested them in 22 hours. A perch measuring 30 c. c. in volume ate 78 chironomid larvæ (having a volume of 4.2 c. c.), digesting them in 46.5 hours at 2.5° C. At 24° C. this perch ate 26 damselfly nymphs (no chironomid larvæ were available) having a volume of 2.5 c. c. and digested them in 23 hours. Taking as a basis for calculation Muttkowski's (1918) estimate of the number of chironomid larvæ in shallow water and recent studies of deep-water fauna by Birge and Juday, there are about 474,750,000,000 in Lake Mendota. The number of perch they would support may be computed roughly: A perch of medium size if eating nothing but chironomid larvæ would average about 4.2 c. c., or 78 individuals of various sizes, per day, which would amount to about 1,533 c. c., or 28,470 individuals per year. On such a basis the chironomid larvæ could support 16,675,447 perch per year.

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[a] On Nov. 23, 1917, calcium carbonate crystals were found in one of three perch caught at a depth of 2.5 m. in Lake Mendota.

Such methods of estimating are highly speculative at present but give some gross approximation as to the number of perch that might possibly live in Lake Mendota. After studies have been completed which are now being carried on by the Wisconsin Geological and Natural History Survey concerning the animal population of the various lake habitats and the chemical composition of animals which may serve as fish food, and after the writers have made more extensive experiments on the rate of consumption and digestion of different foods, it will be possible in a few years to speak with more authority concerning the productive capacity of lakes. Pütter (1909) has made careful studies of the food requirements of the smelt and herring, which he expresses in terms of copepods. He states that the smelt needs the following numbers of copepods daily during its first season: May 6 to 29, 124 (1 mg.); May 29 to July 29, 248 (2 mg.); July 29 to September 25, 496 (4 mg.). The herring needs: July 13 to 30, 3,300 (26.6 mg.); July 30 to September 20, 6,080 (49.9 mg.); September 20 to November 15, 4,470 (38.8 mg.). To keep in good condition the smelt would require 100 to 500 copepods daily during its growth period, and the herring 3,000 to 6,000.

Little is known concerning details of digestive processes in fishes. Denis (1912) has measured the amount and composition of urine given off by sharks and goosefishes. Knauthe (1898) states that the amount of nitrogen given off increases as the temperature of a fish rises. Greene (1914) has made interesting studies of the utilization of fat by the salmon during its migration. Pütter (1909) found that a goldfish would change the contents of its intestine more often if peristalsis was artificially stimulated by suspending fine sand in the water. He also analyzed the substance in the carp and found it to contain: Water, 78.85 per cent; dry substance, 21.16 per cent; albumen, 17.38 per cent; fat, 2.57 per cent; ash, 1.22 per cent; nitrogen, 2.91 per cent. Knauthe (1898) carried out extensive feeding experiments with carp. He states that, when no protein was fed, carp slowly became unable to digest pure starch, 10 times the usual amount of nitrogen being given off in the excreta. However, if protein was fed after a long period of exclusive carbohydrate diet, starch was again normally digested. Old fish did well when fed nothing but rice meal, and Knauthe believed this was because the proteins in the gonads were utilized. Fish died on an exclusive diet of lean meat. Ability to digest starch was lowered by deficiency of minerals in the diet. Pütter (1909) states that it was impossible to rear smelt, herring, or carp when they were fed nothing but small crustacea. About the only generalization that can be made from the facts reviewed is that some variety is apparently necessary in fish diet.

In the present work no essentially new contribution has been made to digestive processes in fishes, except for the points already reviewed relating to amounts consumed and the rate of digestion at different temperatures. These observations agree with those of Knauthe (1907) and Fibich (1905). One other interesting fact was noted. During

February, March, and April, 1916, the perch in Lake Mendota and the crappies in Lake Wingra had considerable amounts of beautifully regular calcium carbonate crystals (which were usually embedded in a brownish, amorphous matrix) in their intestines. The food of 10 perch examined on each of the following dates contained the amount of crystals indicated: February 1, 0.5 per cent; March 1, 8.1 per cent; March 29, 12.3 per cent; April 14, 1.2 per cent; April 28, 2 per cent. At the same time the crappies (*Pomoxis sparoides*) in Lake Wingra showed the following amounts: March 11, 4 per cent; March 18, 0.2 per cent; April 22, 0.2 per cent; but the intestines of the perch in Lake Wingra contained none. Two of the perch from Lake Mendota examined on March 29 contained 30 per cent of the calcium crystals. The remainder of the food in one of these consisted of 45 per cent silt and bottom débris, 5 per cent chironomid larvæ, 1 per cent Corethra larvæ, 17 per cent plant remains, 2 per cent filamentous algæ; in the other, of 35.9 per cent silt and débris, 30 per cent plant remains, 3 per cent Corethra larvæ, 1 per cent chironomid larvæ, 0.1 per cent gelatinous alga. Birge and Juday (1911, pp. 108, 171) analyzed the mud from the bottom and the crust from aquatic plants in Lake Mendota. The former contained, in percentages of dry weight, 33.21 per cent, and the latter, 47 per cent of calcium oxide. As has been previously stated, the perch feed largely inshore during February, March, and April, and the two individuals just cited, which showed a high percentage of crystals, also contained bottom mud and plant remains. The crystals may be accounted for on the supposition that calcium carbonate taken in through the mouth is dissolved in the stomach and that crystals form in the intestine as water is withdrawn during absorption.

VARIETY IN FOOD AND ADAPTABILITY IN FEEDING.

Knauthe (1907) pointed out that certain fishes, such as the trout and the perch, changed readily from one type of available food to another; but others, like the pike, the smelt, and the lota, made such changes with difficulty and hence died more often during scarcity of certain foods. The senior writer (1918) developed this idea still further in his studies of the shore fishes of Wisconsin lakes and also demonstrated that different species of fishes manifest a rather marked degree of specificity in choosing food. Each species, even though it may be versatile, shows preferences for particular foods, and some kinds of fishes select from a very limited number of foods. Fishes certainly select specific foods from those available, and it is only by examining the contents of their alimentary canals that preferences can be determined. Abundant foods are often apparently avoided in one lake by a particular fish, but the same food is eagerly eaten by it in another. As Knauthe (1907) says: "The value of materials as food must be determined biologically even more than phenologically or chemically."

One example will illustrate the fact that different species show specific preferences. On April 22, 1916, six species of fish were caught at the same time and place in Lake Wingra, and an analysis of the food eaten gave the following results:

Ten breams (*Abramis chrysoleucas*) had eaten of *Chironomus decorus* larvæ, 3.5 per cent; *Chironomus* sp.? larvæ, 2 per cent; *Cricotopus trifasciatus* larvæ, 2.6 per cent; mayfly nymphs, 2 per cent; chironomid pupæ, 1 per cent; *Cricotopus trifasciatus* pupæ, 1.5 per cent; Hyalella, 0.1 per cent; ostracods, 0.2 per cent; Canthocamptus, 1.5 per cent; Cyclops, 33.8 per cent; *Daphnia pulex*, 19.3 per cent; *Chydorus sphæricus*, 5.1 per cent; *Bosmina longirostris cornuta*, 1.5 per cent; Physa, 2 per cent; Oscillatoria, 4.7 per cent; algæ, 0.1 per cent; flagellates, 0.2 per cent; Volvox, 0.7 per cent; plant remains, 9 per cent; fine débris, 9.1 per cent.

Five crappies (*Pomoxis sparoides*) had consumed of *Chironomus fulviventris* larvæ, 24.2 per cent; mayfly nymphs, 13 per cent; Callibætis nymphs, 7.2 per cent; *Enallagma hageni* nymphs, 6 per cent; chironomid pupæ, 13 per cent; Corixa adults, 3.6 per cent; Hyalella, 3.2 per cent; ostracods, 1.3 per cent; Cyclops, 26 per cent; Daphnia, 2.6 per cent; Bosmina, 0.6 per cent; Eurycercus +; calcium carbonate crystals, 0.2 per cent.

Thirteen perch contained of fish eggs, 0.7 per cent; minnows, 8 per cent; fish remains, 7 per cent; insect larvæ, 1.5 per cent; Protenthes larvæ, 2 per cent; *Chironomus decorus* larvæ, 7.6 per cent; *C. fulviventris* larvæ, 38.2 per cent; *Probezzia pallida* larvæ, 0.5 per cent; caddisfly larvæ, 0.6 per cent; Callibætis nymphs, 7.8 per cent; *Enallagma hageni* nymph, 1.4 per cent; chironomid pupæ, 6 per cent; Hyalella, 1.5 per cent; ostracods, +; Eurycercus, 0.1 per cent; Physa, 6.5 per cent; Planorbis, 0.2 per cent; Pleurococcus, +; Chara, 1.4 per cent; fine débris, 8 per cent.

Though the perch is versatile, it selects preferred foods from the environment, and preferences apparently vary more or less at different ages, seasons, and localities. The staple articles of diet for adult perch throughout the year are chironomid larvæ and cladocerans, but with changing seasons there may be great variation in the proportions of either. Furthermore, perch of the same size caught at the same time and place have usually eaten the same kinds of food, but at times have not. As a rule the nature of the food indicates that it was secured on or near the bottom, but schools of perch are sometimes seen feeding at the surface of the lake. This is particularly true in the early morning.

Judged by the success of line fishing, feeding is largely diurnal, for few perch can be caught at night. This indicates also that perch depend upon their sense of sight to a marked degree, and this view has been supported through the observation of individuals fed in glass aquaria.

In order to discover whether adult perch ate different foods at various depths, comparisons have been made which include all catches in Lake Mendota. These are summarized in Tables 16 and 17. The first shows the percentage of food at different depths; the latter, the kinds of foods which exceeded all others in volume. Both tables show: (1) That food is more varied in shallow water and that it consists largely of chironomid larvæ, Corethra larvæ, Daphnia, Corneocyclas, and bottom mud in the deeper parts of the lake; (2) that the following foods decrease in amount eaten in passing from shallow to deep water—small fishes, mites, adult insects, crayfishes, Hyalella, copepods, snails, leeches; (3) that the following foods increase in passing from shallow to deeper water—insect larvæ, insect pupæ, bottom mud, Cladocera, small clams, oligochætes, plants; and (4) that in general the perch have eaten the foods which are most abundant at the depth where they are caught. This indicates that they do not change rapidly from one stratum to another; that is, there are usually no rapid vertical migrations.

The fact that insect pupæ, largely those of midges, are eaten mostly in deep water indicates that they are secured in the bottom mud before beginning their migration to the surface. Plants occur in greater amounts in perch from deeper water, and this is probably because remains of plants which have been washed loose and broken up by storms are so arranged as to be lying upon the bottom. Deposits of such plants are favorite resorts for insect larvæ. The tables just cited and evidence from many other sources show that the perch usually feed on or near the bottom.

The contrast in the food of perch from different depths may, perhaps, best be indicated by the following specific instances where individuals were caught at the same time:

JULY 1, 1915.

Depth, 18.3 m.; number examined, 9. Food—*Chironomus decorus* larvæ, 21 per cent; *Protenthes choreus* larvæ, 12.4 per cent; *Corethra punctipennis* larvæ, 15 per cent; *Chironomus decorus* pupæ, 21.6 per cent; *Corethra punctipennis* pupæ, 0.5 per cent; mites, 0.1 per cent; ostracods, 0.1 per cent; *Daphnia hyalina*, 13.3 per cent; *Corneocyclas idahoensis*, 8.3 per cent; Hyalella, 0.5 per cent; Gordius (from chironomid larvæ), 6.4 per cent.

Summary.—Midge larvæ, 48.4 per cent; midge pupæ, 22.1 per cent; mites, 0.1 per cent; ostracods, 0.1 per cent; cladocerans, 13.3 per cent; clams, 8.3 per cent; amphipods, 0.5 per cent; Gordiacea, 6.4 per cent.

Depth, 15 m.; number examined, 5. Food—*Chironomus decorus* larvæ, 14 per cent; *Corethra punctipennis* larvæ, 9.4 per cent; *Protenthes choreus* larvæ, 6 per cent; *Chironomus decorus* pupæ, 33 per cent; *Protenthes choreus* pupæ, 7.6 per cent; *Daphnia hyalina*, 10 per cent; Sphaeriidæ, 14 per cent; Gordius, 4 per cent.

Summary.—Insect larvæ, 29.4 per cent; insect pupæ, 40.6 per cent; cladocerans, 10 per cent; clams, 14 per cent; Gordiacea, 4 per cent.

Depth, 4 m.; number examined, 5. Food—Minnows, 19.4 per cent; Chironomus unidentified larvæ, 5.6 per cent; *Chironomus abbreviatus* larvæ, 1 per cent; *Corethra punctipennis* larvæ, 2 per cent; *Chironomus decorus* pupæ, 1 per cent; *Cambarus propinquus*, 36 per cent; Hyalella, 9 per cent; *Eurycercus lamellatus*, 1 per cent; *Physa heterostropha*, 16 per cent; Planorbis, 0.4 per cent; leech, 9 per cent.

Summary.—Fish, 19.4 per cent; midge larvæ, 8.6 per cent; midge pupæ, 1 per cent; crayfishes, 36 per cent; amphipods, 9 per cent; cladocerans, 1 per cent; snails, 16.4 per cent; leech, 9 per cent.

MAY 12, 1916.

Depth, 0.5 m.; number examined, 5. Food—Sucker eggs, 21.8 per cent; *Chironomus decorus* larvæ, 1 per cent; *C. fulviventris* larvæ, 1.6 per cent; *Enallagma antennatum* nymphs, 3 per cent; Argia nymph, 1 per cent; *Leptocerus ancylus* larvæ, 8 per cent; *Sialis infumata* larvæ, 16.9 per cent; *Hyalella azteca*, 0.8 per cent; *Physa heterostropha*, 8 per cent; *Nephelopsis obscura*, 19 per cent; bud scale, 0.4 per cent; Lemna, 1.5 per cent; filamentous algæ, 2 per cent; sand, 13 per cent; débris, 2 per cent.

Summary.—Fish eggs, 21.8 per cent; insect larvæ, 31.5 per cent; amphipods, 0.8 per cent; snails, 8 per cent; leeches, 19 per cent; plants, 3.9 per cent; sand, 13 per cent; débris, 2 per cent.

Depth, 4 m.; number examined, 2. Food—Perch eggs, 99.7 per cent; *Chironomus decorus* larvæ, 0.1 per cent; *Sialis infumata* larvæ, 0.1 per cent.

Depth, 7 m.; number examined, 3. Food—*Chironomus decorus* larvæ, 51.6 per cent; *Protenthes choreus* larvæ, 21.7 per cent; *Corethra punctipennis* larvæ, 4.7 per cent; *Sialis infumata* larvæ, 15 per cent; *Amnicola limosa*, 1.3 per cent; leech, 5 per cent; fine mud, 0.7 per cent.

Summary.—Insect larvæ, 93 per cent; snails, 1.3 per cent; leeches, 5 per cent; mud, 0.7 per cent.

Depth, 15 m.; number examined, 3. Food—*Chironomus decorus* larvæ, 8.3 per cent; *Protenthes choreus* larvæ, 8.3 per cent; *Corethra punctipennis* larvæ, 2 per cent; *Leptocerus ancylus* larvæ, 1.3 per cent; *Sialis infumata* larvæ, 5 per cent; oligochætes, 28.3 per cent; bottom mud, 46.7 per cent.

Summary.—Insect larvæ, 24.9 per cent; oligochætes, 28.3 per cent; bottom mud, 46.7 per cent.

Depth, 17 m.; number examined, 3. Food—*Chironomus decorus* larvæ, 18.7 per cent; *Protenthes choreus* larvæ, 8.7 per cent; *Corethra punctipennis* larvæ, 1 per cent; oligochætes, 46.7 per cent; *Corneocyclas idahoensis*, 0.7 per cent; bottom mud, 24.3 per cent.

Summary.—Insect larvæ, 28.4 per cent; oligochætes, 46.7 per cent; clams, 0.7 per cent; mud, 24.3 per cent.

Except for the food of a few young perch and for the comparison (p. 319) between the examinations in Lakes Wingra and Mendota, no particular studies have been made of the perch from different lakes. It is probable that the feeding habits are rather uniform, but the food varies according to conditions in different localities.

VARIATION IN FOOD AT DIFFERENT AGES.

In order to determine what foods were eaten by young perch during the first summer after they hatched, collections were made with a minnow seine at intervals during 1916 in shallow water east of the base of Picnic Point in Lake Mendota. The results of the food examinations are summarized in Table 18. The perch were very uniform as to size, and it will be noted that the average length showed a regular increase as the season advanced. The table shows that Cyclops, other small crustaceans, and minute insect larvæ are replaced to a large extent by Hyalella and good-sized insect larvæ as the perch increase in size.

To compare the food of the perch summarized in Table 18 with the food of those from another place in Lake Mendota on a date close to one of those utilized in the usual locality, 10 small perch were collected from the mouth of Six Mile Creek on August 8, 1916. They had eaten of *Tanypus monilis* larvæ, 2.5 per cent; *Chironomous lobiferus* larvæ, 7.8 per cent; mayfly nymphs, 18.5 per cent; Bætis nymphs, 8 per cent; *Cænis diminuta* nymphs, 23.4 per cent; Corixa nymphs, 16.3 per cent; *Chironomus lobiferus* pupæ, 13.1 per cent; *Hyalella azteca*, 10.3 per cent; ostracods, +. If these results be compared with those for August 7, in Table 18, it is apparent that only three of the same items have been eaten in the two localities, yet there is general similarity. About the same types of foods are eaten in about the same proportions.

Through the kindness of A. R. Cahn we were able to examine small perch from Oconomowoc Lake. Though the individuals were more variable in size than those examined in Lake Mendota, the same food changes are evident (Table 19). Small insect larvæ and entomostracans are succeeded by larger larvæ and Hyalella.

If these two tables showing the food of small perch are compared with Table 9, which gives the results for adults, it is evident that at the close of the first summer the food of the young has become like that of adults.

RATE OF GROWTH ON DIFFERENT FOODS.

To be of most significance, the determinations of the rate of growth should be made on perch of various ages at different temperatures. Knauthe (1898) performed experiments which indicated that metabolism is more rapid in young fish than in old and that more protein food is necessary during youth. Older fish need apparently more mineral than young. Pütter (1909) says that the smelt and herring require nearly twice as much food after growing for a month. He found that a carp after two summers weighed about 500 g. and that it would increase to 1,250 g. by the middle of the next August. In this paper it has already been shown that digestion is more rapid in perch at higher temperatures (p. 313).

We have been able to test the rate of growth in perch of one size only and at one temperature. From August 19 to September 18, 1916, when the temperature of the water varied from 20 to 16.8° C., 26 small perch were placed in separate glass jars having a capacity of 4 liters each, and in lots of 3 were fed, as follows:

1. Fish liver and flour mashed and mixed together.
2. *Hyalella azteca* alive.
3. Plankton fresh from Lake Mendota. It consisted of Daphnia, 95 per cent; Leptodora, 4.5 per cent; algæ, chiefly Lyngbya, 0.5 per cent.
4. Earthworms alive.

5. Insects—Corixa, Plea nymphs, Notonecta nymphs, damselfly adults, crickets, midges.
6. *Chironomus decorus* larvæ alive.
7. Fish cut into small pieces.
8. "Normal" diet, consisting of all the kinds of food fed under 1 to 6, but no single one in large enough quantity to give complete satisfaction by itself. The two jars in which these fish were kept contained also Elodea.
9. Starved.

The fish ate all classes of food readily except the insects. Although Corixa and other varieties which occurred in perch of similar size in nature were offered, they were never taken in any quantity and were often refused altogether. The practice with all the foods was to change the water each morning and in midafternoon to add a fresh supply of food, which exceeded what might be eaten before the next day.

The results of these experiments are given in Table 20. The foods would come in the following order, as judged by the rate of gain in weight and volume: Earthworms, Entomostraca, chironomid larvæ, amphipods, fish, "normal," liver, and flour. The three perch fed adult insects lost almost as much as those which had nothing. It will be noted that there is no correlation between the gains in weight and volume. It is difficult to understand why the three "normal" individuals which were fed a variety did not gain as much as others which received only one kind of food during the entire month. Perhaps the extra energy required to digest a variety more than compensated for the diversity of chemical substances obtained.

COMPARISON OF FOOD OF PERCH IN LAKE MENDOTA AND IN LAKE WINGRA.

The fact that perch are individually smaller in Lake Wingra than in Lake Mendota is probably due to a number of causes, but one would naturally turn first to differences in food for an explanation of such variance. In Table 21 the various foods eaten by the perch in each lake is given by months. The averages show that fish, insect larvæ, insect pupæ, adult insects, isopods, and copepods are eaten in greater amounts in Lake Wingra than in Lake Mendota; the opposite is true of mites, crayfishes, amphipods, ostracods, cladocerans, snails, clams, leeches, oligochætes, plants, silt and débris, and $CaCo_3$ crystals. In all but two months in Lake Wingra, insects as larvæ, pupæ, or adults form half, or more than half, of the food. In Lake Mendota the months are equally divided, as regards the particular foods eaten in maximum amounts, between Cladocera and insect larvæ.

An examination of figures 6 to 29 will show many other minor differences in details between the two lakes. Among the insects the chironomids do not differ much, but Wingra excels in chironomid pupæ and in odonate and mayfly nymphs. Among the cladocerans the amount of Leptodora was about the same in the two lakes (4.6 to 4.7 per cent); Daphnia was in excess in Mendota (20.9 to 4.8 per cent), and Eurycercus in Lake Wingra (0.1 to 30.3 per cent).

Another difference between the perch in the lakes under consideration is shown in Table 22, which demonstrates that there are two seasons in Wingra when many of the perch have little or no food in them and only one in Mendota. The empty perch in April are doubtless due to the neglect of feeding on account of breeding. The fasting period in Wingra during August and September has no counterpart in Mendota and is equally characteristic of both sexes. It is probably due to the continued high temperature, from which there is no escape, as there is in Mendota, and to the extreme turbidity of the water. In late summer the water in Lake Wingra is murky with myriads of algæ. The perch are pale in color and apparently in poor condition.

The chief respect in which the perch of Wingra differ from those in Mendota, in regard to food, is (1) that they eat more insect larvæ and less of entomostracans, (2) that through most of the year they apparently feed more among water plants, and (3) that they have longer periods when little or no food is eaten.

COMPARISON OF FOOD OF PERCH AND CRAPPIE IN LAKE WINGRA.

From February to November, 1916, the food of crappies (*Pomoxis sparoides*) from Lake Wingra was studied, and the results for the nine months may be compared with those for perch. The total percentages of foods eaten by both was as follows, the perch being placed first in each case: Fish, 12.7 to 8.8; insect larvæ, 52.8 to 25.5; insect pupæ, 11.4 to 7.9; adult insects, 1.3 to 4.8; mites, 2 to +; amphipods, 0.3 to +; clams, 0.05 to 0; leeches, 0.2 to +; oligochætes, 0.1 to 0; plants, 3 to 0.4; débris, 1.2 to 1. In other words, the perch eats more of fish, insect larvæ, insect pupæ, mites, amphipods, snails, clams, leeches, oligochætes, plants and débris; the crappie more of adult insects, ostracods, copepods, cladocerans. These proportions clearly indicate that perch feed largely on or near the bottom, while crappies hunt more toward the surface and among water plants.

The structure of the crappie is more specialized than that of the perch and would indicate greater adaptation to particular conditions. Its mouth is more upturned, suggesting feeding toward the surface of the water, and the body is more compressed, indicating a habitat among aquatic vegetation. A full account of the observations on the crappies of Lake Wingra has already been published (Pearse, 1919).

RESPIRATION.

A perch must obtain the oxygen necessary for its metabolic activities from the water in which it lives. Water free to absorb gases from the atmosphere will contain about 35 per cent oxygen, 65 per cent nitrogen, and a trace of carbon dioxide. The total amount of gas which may be absorbed varies with the temperature of the water. At 0° C. a liter of water, when the pressure is 760 mm., can absorb 41.14 c. c. of oxygen, 1,796.7 c. c. of carbon dioxide, and 20.35 c. c. of nitrogen. At 20° C. the amounts will be: Oxygen, 28.38 c. c.; carbon dioxide, 901.4 c. c.; and nitrogen, 14.03 c. c.; at the boiling point of water none of the gases will be absorbed. When there are many living plants present, the amount of oxygen may rise above the saturation point; when oxygen is used up (decomposition, respiration, etc.), it may fall much below saturation or even be absent altogether. A perch, then, normally lives in water which may vary greatly in its gaseous content at different seasons.

Supersaturation with oxygen appears to offer no particular difficulties for fish, but when this gas is scanty there may be trouble in obtaining a sufficient supply for respiratory needs; yet some species are able to live in water containing a very small amount. Winterstein (1908) states that 0.7 c. c. of oxygen per liter was enough to sustain life in *Leuciscus erythropthalmus*, but when the amount was decreased as low as 0.4 to 0.5 c. c., death ensued. Most fishes show signs of distress when the oxygen is 1 to 4 c. c. per liter. In natural bodies of water the carbon dioxide usually increases as the oxygen decreases, but in amounts such as occur in nature its presence does not appear to be particularly detrimental, provided enough oxygen is also present. Winterstein (1908), however, thinks that fishes are affected by the presence of carbon dioxide, because some species succumb when its tension is only 8 to 12 per cent of the total pressure of gases; but he also found that in two instances as much as 144.7 and 204.6 c. c. per liter were required to overcome Leuciscus. Shelford and Allee (1913) conclude that the narcotic effect of carbon dioxide is more important for fishes than its action as an acid. Various species tested by them were affected injuriously when the amount present was from 5 to 37.5 c. c. per liter.

As a rule, four factors are of chief importance for the normal respiration of fishes: (1) Sufficient oxygen for metabolism, (2) lack of enough carbon dioxide to be injurious, (3) favorable temperature, and (4) proper reaction (salinity or acidity) of water. Though oxygen and carbon dioxide are the only gases which usually affect the respiratory activities of fishes, others may be of some importance at times. Methane and ammonia sometimes occur in certain restricted localities, and are injurious; nitrogen may, if present in unusual amount, give rise to the gas disease (Marsh and Gorham, 1905). But troubles from such gases are of rare occurrence. Gardner and Leetham (1914) have shown that a trout uses twice as much oxygen for respiration if the temperature of the water about it is raised from 10 to 20° C. Wells (1913) found that fish died more quickly in alkaline than in acid water when gas conditions were poor. Marsh (1910) asserts that fish will not live in well-aerated distilled water and that they are very susceptible to dilute solutions of mineral acids.

The respiration of fishes, then, requires reasonably pure water of proper chemical reaction and with a sufficient supply of oxygen. The experiments of Shelford and Allee (1913, 1913*a*) have demonstrated that fishes respond to the conditions in their environment in such a way as to spend most of their time in the optimum. Fishes are able to discriminate variations in the gas content of the water, and when placed in a graded series usually spend the most time where conditions are best. They are apparently more stimulated to turn away from unfavorable regions by the presence of carbon dioxide than by deficiency in oxygen, some turning back upon encountering 1.5 c. c. of carbon dioxide per liter. "We have in the experiments good evidence that fishes turn back from waters high in carbon dioxide and low in oxygen with precision and vigor. Also that if they enter such localities, they can not behave normally and may soon die."[a] Wells (1913) also has shown that fishes are most active when in water containing a scanty supply of oxygen and has demonstrated (1915) that a number of fresh-water species select slightly acid water in preference to that which is alkaline. He also asserts (1913) that the future will show that the reactions of fishes are of more importance than their resistance to unfavorable conditions. Death after reaching the vital limit is unusual, but the avoidance of conditions which may mean death is of frequent occurrence. The behavior of fishes is such that it would usually keep them in optimum conditions; yet Juday and Wagner (1908) found that lake trout commonly entered deep waters which contained so little oxygen that they could not live in them for any length of time. Paton (1902) also observed that brook trout which were kept in water containing very little oxygen were able to survive for some time by remaining inactive on the bottom and thus reducing their metabolism to a minimum. This brings us to the resistance of fishes to a marked deficiency in oxygen or to an unusually large amount of carbon dioxide.

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[a] Shelford and Allee, 1913, p. 251.

Packard (1905, 1907, 1908) kept top minnows, *Fundulus heteroclitus*, in oxygen-free water and found that they were able to live about three hours. He believes that these fishes must get oxygen from other sources than the atmosphere. His experiments support Mathews' (1905) theory of respiration, which supposes that the oxygen of the atmosphere acts as a depolarizer and combines with nascent hydrogen produced during metabolism. If oxygen can be replaced by some other substance which will neutralize hydrogen, its presence is not necessary. Packard found that he could prolong the life of Fundulus in water which contained no oxygen by injecting carbohydrates into the body cavity. Wells (1913) determined that abundant oxygen and carbon dioxide was less injurious to fishes than a very small amount of both gases or than much carbon dioxide and little oxygen. He says (p. 345): "Oxygen in large amounts (10 c. c. per liter) antagonizes the detrimental effects of high carbon dioxide (50 c. c. per liter)." He also found that the most active fishes succumbed to a large amount of carbon dioxide before more sluggish individuals, and that oxygen deficiency was more quickly fatal when the water was alkaline than when it had an acid reaction. The observations just reviewed, then, indicate (1) that fish are able to live for some time in water without oxygen; (2) that lack of oxygen is generally more injurious than excess of carbon dioxide; and (3) that gas conditions unfavorable for respiration are more quickly fatal in water with an alkaline reaction.

The general resistance which fishes show to suffocation is in many species assisted materially by the use of the swim bladder as a storage reservoir for oxygen. This organ apparently serves various functions and in different fishes may be used as a lung, an organ for making sounds, a hydrostatic organ, and as a respiratory reservoir. Woodland (1911) proved the hydrostatic function by weighing fish after subjecting them to different pressures. The use of the bladder as a storage reservoir for oxygen has been the subject of a number of investigations. Tower (1902), for example, studied a number of marine fishes and found there were three gases present—oxygen, carbon dioxide, and nitrogen; that the amount of carbon dioxide might increase a little (0.25 per cent) during suffocation, but that it was usually 0.06 to 0.1 per cent of the total gases; and that the deeper the water from which fishes were taken, the higher the proportion of oxygen (in some fishes captured at considerable depths the gas in the bladder was practically all oxygen). Bridge (1891) showed that the secretion of gases into the swim bladder was under the control of the nervous system; and he found that there was usually an increase in the amount of carbon dioxide when the fish died of suffocation. The Cambridge Natural History states that in general the amount of oxygen in the bladder is less in fresh-water fishes than in those from the ocean. In fishes like the perch, in which the swim bladder has no duct connecting it with the outside, its functions are confined to storing reserve oxygen and regulating the specific gravity of the body (hydrostatic function). Finally, the density of the water in which fishes live affects respiratory activities. As pressure grows greater on account of increase in depth, the ability of the water to absorb gases is also increased. Furthermore, the comparative "hardness" or "softness" of water not only affects the density, but has a marked influence on the pressure of the gases present in solution. Sumner (1906) asserts that the membranes of fresh-water fishes are highly adapted to resist changes in density. There is an "irreducible minimum" of salts in the blood which is not released even when the surrounding water has a very low salt content. Garrey (1905) found the osmotic pressure of blood of marine fishes was about half that of sea water.

With this brief review of facts gleaned from literature on the respiration of fishes, the discussion will now be turned to the discoveries made during the present investigations in regard to the respiratory activities of the perch in Lake Mendota.

During the summer of 1915 it was noticed that many fish caught in gill nets in Lake Mendota were dead, and that there was a greater mortality in the region of the thermocline and below it than above (fig. 31; Table 2). Of 2,194 perch caught, 343 were dead and 1,154 alive above the thermocline; 610 dead and 87 alive below. This indicated that perch commonly entered water which contained too little oxygen for respiration. During the summer of 1916 careful observations were again made, and the same results were obtained. Though perch were usually most abundant immediately above the thermocline, large catches often occurred just below it, where there was no oxygen.

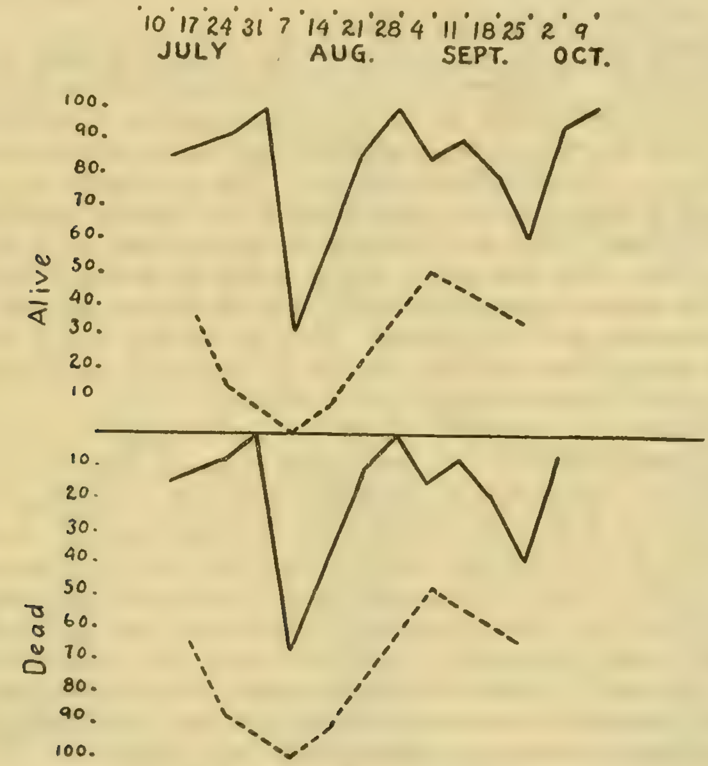

FIG. 31.—Percentage of perch caught alive or dead in gill nets above and below the thermocline, Lake Mendota, 1915. ——, above thermocline; - - - - - -, below thermocline.

The next problem was to discover how long perch could live in the oxygen-free water below the thermocline. Accordingly, from August 30 to September 4, 1916, when the amount of oxygen at a depth of 13.5 m. was 0.05 c. c. per liter and the carbon dioxide was 5 c. c. per liter, perch were let down into the stagnant region and left for various periods of time. The results of the experiments are shown as follows:

Hours submerged.	Perch used.	Perch surviving.	Hours submerged.	Perch used.	Perch surviving.
0.5 to 1	6	5	2 to 2.5	6	2
1 to 1.5	2	2	3	6	0
1.5 to 2	6	2	4	6	0

It will be observed that some perch lived for over two hours, but that none survived for three. This suggested that perch might be able to enter the lower waters of the lake with impunity to take advantage of the abundant food supply there, coming up above the thermocline at intervals to breathe.

This possibility made it necesary to observe the behavior of perch in water from below the thermocline. On September 4 water was pumped up from 13.5 m. (oxygen, 0.06 c. c. per liter; carbon dioxide, 5 c. c.) into a large aquarium on the deck of a boat. Samples taken from the water in the aquarium showed that it contained about 0.3 c. c. of oxygen and 5 c. c. of carbon dioxide per liter. Nine fish, caught in a gill net half an hour before at a depth of 11.6 m., were placed in the aquarium and their behavior observed for two hours. They were compared at intervals with perch caught at the same time and place, which were kept in a large cage at the surface of the lake. One of the fish in the stagnant water turned on its side and became immobile (except for respiratory movements) after four minutes. After half an hour several were lying on their sides, but after an hour and forty minutes one individual was still right side up and, though inactive, appeared to be in normal condition.

On the following day two perch, caught an hour before at 11.7 m., were again placed in water pumped from 13.5 m. into a glass aquarium, and their behavior was observed for an hour. Both of these individuals turned belly up within a few seconds; one floated at the top of the cage, but the other at times was at the bottom and at times at the top. At intervals both righted themselves, moved the fins, and wiggled about actively. After being in the stagnant water for an hour both were taken out and placed in the lake just below the surface. Half an hour later both had recovered, were right side up, and apparently in good condition. Two hours later both were released and swam away. During the time the perch were in the stagnant water the rapidity of their respiratory movements was observed, and the results, showing the number of respiratory movements per minute, are given as follows:

Time.	No. 1.	No. 2.	Time.	No. 1.	No. 2.	Time.	No. 1.	No. 2.
10.03	46	46	10.17	43	48	10.41	34	35
10.05	....	56	10.25	52	53	10.49	32	28
10.07	41.2	48	10.27	41	....	10.55	25	28
10.09	....	45	10.33	....	43	10.57	21	33
10.11	46	....	10.35	0	39	11.00	20	31
10.13	47	47	10.38	0	35			

One individual stopped making respiratory movements for over two minutes in the midst of the experiment. In general, the rate of respiration decreased, but when the fish were placed in the lake again the rate rapidly increased. The rate of those in the stagnant water was considerably less than that of those observed simultaneously in a cage in the open lake. But the water from 13.5 m. was cool (15° C.), and it would therefore be expected that the perch would respire at a slower rate than when in surface water (21.6° C.). In order to determine the normal rate of respiratory movements at different temperatures two healthy perch were observed in the laboratory on November 29, and the results are summarized as follows:

Temperature (degrees centigrade)	8	16	20	25
Movements per minute	24.1	38.5	45.6	59.3

The data indicate that the rapidity of the respiratory movements of the fish placed in stagnant water was not materially increased or decreased by such treatment.

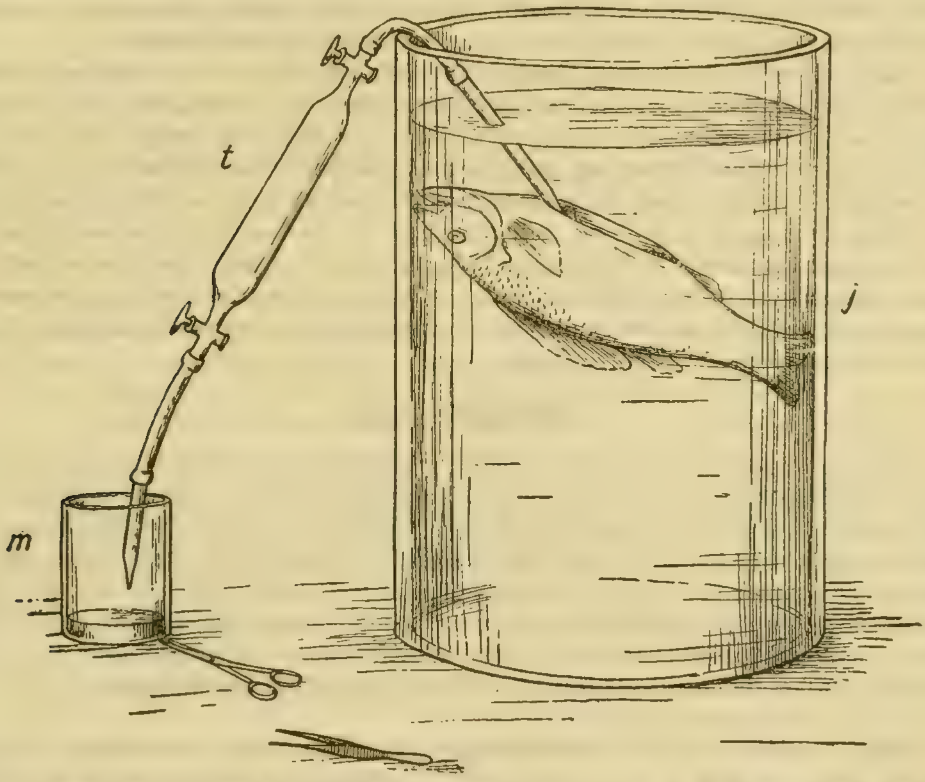

FIG. 32.—Collecting tube and method of collecting gas from perch swim bladders. *j*, jar full of stagnant water continually pumped from depths of lake; *m*, small vessel for collecting mercury; *t*, collecting tube filled with mercury.

The experiments described show that perch in Lake Mendota commonly enter the stagnant water below the thermocline and that they may remain there for an hour or two without suffocating. These facts suggested that perch might make use of the oxygen in the swim bladder while in the stagnant areas, and experiments were performed which showed the supposition to be correct. From August 23 to September 24, 1916, fishes were lowered in wire cages to depths varying from 12 to 13.5 m. The amount of oxygen at such depths was about 0.05 c. c. per liter and the carbon dioxide, 5 c. c. per liter. The perch were allowed to remain for varying lengths of time in the stagnant water and then were pulled quickly (10 seconds) to the surface and placed in a large jar of water pumped from the same depth at which they had been submerged. They were opened as soon as possible under water and the gas in the bladder siphoned out into a mercury-filled collecting tube (fig. 32) of 5 c. c. capacity. The samples were carried into the laboratory in the collecting tubes and analyzed with a Haldane apparatus, the oxygen being absorbed with 10 per cent alkaline pyrogallol and the carbon dioxide with 10 per cent potassium hydroxide. Every time samples were taken from perch which had been submerged in deep water, two or three control individuals which had been in a fish car at the surface were also tested. The details of the results of the analyses are shown in Table 23, and a summary is given in Table 24. Though considerable variation is shown, the latter table indicates that the oxygen in the bladder was used up while the perch were in the stagnant water, but the carbon dioxide did not increase.

From the studies in Lake Mendota the following facts have been ascertained: (1) Perch commonly go into the stagnant water below the thermocline, where there is only a fraction of 1 per cent of oxygen per liter; (2) they may remain there for two hours or more without suffocating, but it is doubtful if they would feed for more than a few minutes; (3) when perch invade water which does not contain sufficient oxygen for respiration they apparently draw to some extent on the reserve in the swim bladder; (4) if through the action of the bladder as a hydrostatic organ a perch is adjusted to pressure conditions above the thermocline, it will, if it invades the lower regions where it is overcome by lack of oxygen and excess of carbon dioxide, tend to float up into levels where gas conditions are more favorable.

REPRODUCTION.

It has already been pointed out that the perch in Lake Wingra are generally of smaller size than those in Lake Mendota. This backwardness in growth, however, does not appear to retard the attainment of sexual maturity (Table 25). Judging by the measurements made on individuals from a school of young perch which remained near the base of Picnic Point (fig. 2) during the summer of 1916 (Table 18), and by observations on the gonads of half-grown perch at various seasons, the authors believe that perch may become sexually mature in Lake Mendota at the end of two years of growth. Meek (1916), speaking of conditions in Europe, says: "The perch appears to become mature when it is three years old."

After a perch attains sexual maturity the gonads in both sexes pass through a regular cycle of seasonal changes. After spawning is completed, the gonads remain small until late summer and then increase very rapidly in size for a month or more. By September they are almost as large as in the spring. The growth of the gonads, then, takes place for the most part in the summer, when food is most abundant, and there is little change in size during the winter months. By November, perch caught in deep water (18 to 20 m.) will often shed eggs when brought to the surface. Such individuals are, of course, not completely "ripe" but emit eggs on account of the decrease in pressure. Prof. C. L. Turner (1919) has made a careful study of the volumetric and cytological changes in perch gonads at Milwaukee, and his paper gives detailed information concerning the annual reproductive cycle.

The spawning season in Lake Wingra comes earlier than in Lake Mendota. This is due largely to the fact that the ice goes out sooner and the smaller volume of water warms up more rapidly. Figures 3 to 6 show that the period of activity associated with the migration of perch into shallow water for spawning came nearly a month earlier in Lake Wingra. In the spring of 1916 the ice left Lake Wingra March 20 and Lake Mendota April 8. The temperature just below the surface on April 18 was 10.6° C. in Lake Wingra and 4.6° C. in Lake Mendota. Our observations agree with those of Forbes and Richardson (1908), who state that the spawning of perch takes place in April and May, when the temperature of the water is 7 to 10° C.[a] Compared with other species of fishes and amphibians which lay eggs in the spring, the perch spawn rather early. During the spring of 1916 the following sequence was observed in Lake Mendota: April 12, the swamp-tree frog, *Corophilus nigritus*, was singing in the swamps along shore; April 20 to May 7, perch were spawning; May 2, the larvæ of the orl fly, *Sialis infumata*, were migrating on shore; May 12, suckers, *Catostomus commersonii*, were spawning; May 30, crappies and dogfishes were frequenting bare spots alongshore; and June 19, crappies in Lake Wingra were spawning. When most of the perch in Lake Mendota were spawning, the majority of those in Lake Wingra were already spent. In the autumn also the gonads of the perch in the smaller lake were noticeably earlier in reaching the large size characteristic of the cooler months, and this is again correlated with the earlier cooling of the lake.

Perch come into shallow water alongshore to breed. The males precede the females and remain longer on the spawning grounds. This means that there are many more males than females in shallow water from the middle of April until the early part of May.[a] For example, on April 28, 1916, a 1-inch mesh gill net, pulled from a depth of less than 3 m., contained 380 perch, and all but four were ripe males (Table 26). There were three ripe females and one immature male. On May 2 and 12 there was still a great preponderance of males in the nets set in shallow water, but on later dates the sexes became more or less similarly distributed at all depths. The males evidently came inshore and remained during the entire spawning season; the females left deep water for only a short time to lay their eggs. Meek (1916, p. 281) records similar behavior for the plaice: "Results appear to show that the males appear first at the spawning ground and remain during the season, whereas the females depart shortly after the ova are shed." Abbott (1878) states that perch go in pairs to the spawning beds. In our gill-net catches a ripe female was often surrounded by several males. This indicates that a female may be attended by more than one male.

Breeding instincts appear to dominate feeding instincts at the time of spawning. Table 22 shows that about 6 per cent of the individuals captured during the breeding season contained no food, and it was mostly the males that were empty. Another difference in feeding activities was noted between the sexes. The fishermen on Lake Mendota have stated on various occasions that they always caught more females than males when fishing in deep water through the ice with hook and line. The following observations support this view: December 29, 1916, 13 m., 40 females, 0 males; December 30, same place, 38 females, 2 males; January 4, 1917, 15 m., 5 females, 3 males; January 6, same place, 9 females, 7 males; January 8, same place, 34 females, 7 males; January 25, 18 m., 28 females, 10 males. These facts indicate that the females feed more actively during the winter or that they exceed the males in numbers in the deeper parts of the lake.

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[a] On May 7, 1920, at 4.25 p. m., the writer set two 4 by 75 gill nets, tied end to end, at a depth of 2.7 m. on the south shore of Lake Mendota. At 10.45 a. m. on May 8 the 1½ inch mesh net contained a rock bass and a pickerel. The 1-inch mesh net at 8.15 a. m. on May 8 had caught 921 ripe male perch, 10 ripe female perch, 9 spent female perch, 4 female perch which had whitish eggs in their ovaries, and 1 mud puppy. The food of the last consisted of crayfishes, 92; Physa heterostropha, 4; plant remains, 2; Leptocella larva and case, 1; perch eggs, 1. The water temperature (first figure in each set indicating depth in meters; second, degrees centigrade) was as follows: 0, 11; 1, 10.8; 3, 10.4; 4, 10; 5, 9.7; 6, 8.1; 7, 7.2; 8, 7.1; 10, 6.9; 13, 6.5; 15, 6.4; 18, 6.1; 20, 5.8; 23.5, 5.6.

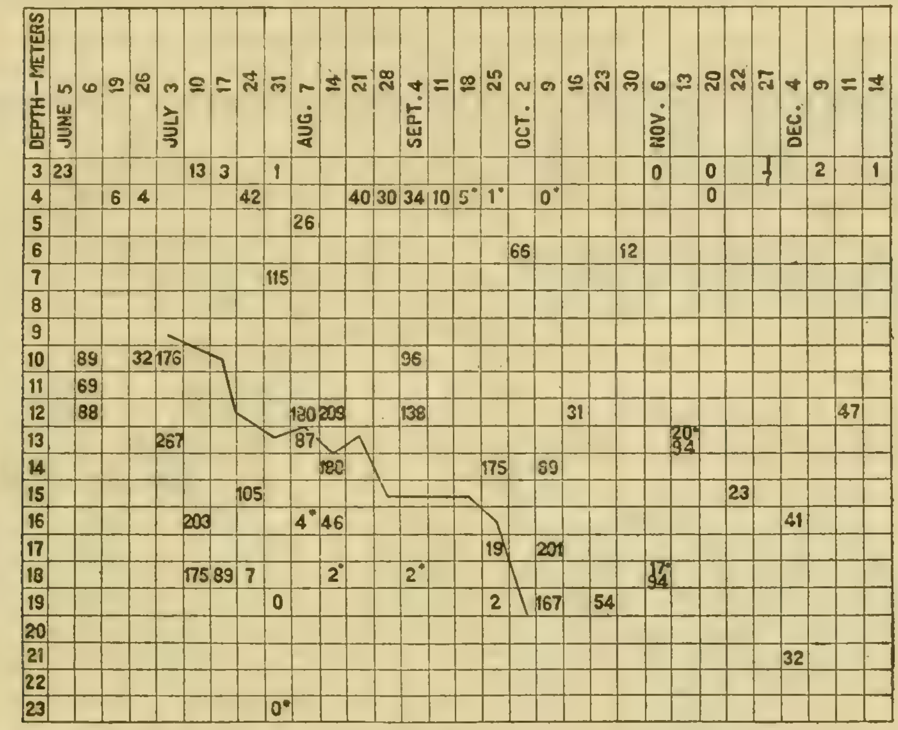
The egg string deposited by a perch which had been kept for several months in a running-water aquarium is shown in Plate LXXXIII, figure 2. This contained 2,650 eggs and was deposited on May 1, 1916, when the water temperature was 12° C. A string was also laid by another individual in the same aquarium on April 18. Forbes and Richardson (1908) mention a string recorded in one of the laboratories of this Bureau which measured 88 inches in length and weighed 41 ounces after the water had been drained from it. The strings swell very rapidly and harden somewhat after leaving the body of the female. They are often thrown over stones, plants, or other objects in the water. Gorham (1912) states that they may be attached to willow roots. The same authority says that eggs hatch in 8 to 10 days and that the small fry hide in nooks alongshore until they appear in schools as fingerlings. Hankinson (1908) and Reighard (1915) mention seeing schools of small perch in shallow water, and the latter notes that there may be small fishes of other species with them. On August 23, 1916, a school of about a thousand young perch was observed near our dock just north of the University of Wisconsin, and it remained in that locality for over a week.

Meek (1916, p. 290) says of the European perch: "The larva measures about 5 mm. when hatched, and in the course of a year the young attains a length of 6 cm., and in two years about 13 cm." We have already noted that perch hatched in the spring of 1916 in Lake Mendota had attained by August 30 a length of 68 mm., without the tail fin, and that perch less than 130 mm. long were sexually mature (Table 25).

MIGRATIONS.

The perch in lakes frequent various localities at different times. In general, migrations are correlated with the changes accompanying the rhythmical sequence of day and night or with those associated with seasonal succession. In order to secure data on the numbers of perch at different depths, fishing was carried on simultaneously at various levels. The catch per hour in a gill net gives a fair idea of the number of perch present, but rather wide seasonal variations are to be expected. Fishes will not be captured unless they are moving, and the lesser activity accompanying lower temperatures will cause smaller catches. Another means the authors have used for judging the number of fishes present in any locality is by the catch per hour with hook and line. During stormy weather the number of perch secured in Lake Wingra from a drifting rowboat with hook and line often exceeded that taken in gill nets, probably because the shallowness of the lake made it inexpedient for the fishes to move about much in windy weather. Neither gill nets nor hooks give accurate data as to the actual numbers present. However, they do give information which is of value for judging comparative numbers when they are used simultaneously at various depths.

An examination of Tables 2 to 5 and 27 shows several points of interest in regard to the abundance of fishes at various seasons, and it is possible to make a number of generalizations from the data presented. In Lake Mendota the course of the annual migration is pretty definite. In the winter most of the perch are in deep water. As soon as the lake is free from ice there is a migration inshore for spawning, but the perch soon return to deep water and remain there until the lack of oxygen drives them into shallower regions. As soon as the autumnal overturn renews the oxygen the perch return for the most part to the depths of the lake. Less marked migrations of the same general type also take place in Lake Wingra, but there is no stagnation period in the summer. Figures 33 and 34 bring out a point which has already been discussed to some extent under food and respiration; that is, though the perch are obliged to live above the thermocline from August to October, they descend at intervals into the cool, stagnant region below, probably to take advantage of the abundant food there. Wells (1915) has pointed out that fishes generally prefer water which has a slightly acid reaction to that which is neutral or alkaline. Of course, such behavior would tend to keep perch in deep water or near the bottom vegetation. Gurley (1902) is an ardent advocate of temperature as the controlling factor in the seasonal migrations of fishes, but in Lake Mendota it can have but slight influence. The perch come into shallow water in spring, when the temperature is low, uniform at all depths, and the same as that which has prevailed for several months; in autumn they descend into deep water when the temperatures are again uniform throughout the lake. The food and the net and line catches both indicate that the perch remain on or near the bottom and in as deep water as possible throughout the year. The migrations into shallow water are to spawn and to escape stagnant conditions during the summer.



DEPTH—METERS	JUNE 5	6	19	26	JULY 3	10	17	24	31	AUG. 7	14	21	28	SEPT. 4	11	18	25	OCT. 2	9	16	23	30	NOV. 6	13	20	22	27	DEC. 4	9	11	14
3	23					13	3		1														0		0		[illegible]		2		1
4			6	4				42				40	30	34	10	5*	1*		0*						0						
5										26																					
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8																															
9																															
10		89		32	176									96																	
11		69																													
12		88								180	209			138						31										47	
13					267					87														20* 34							
14											180						175		89												
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19									0								2		167		54										
20																															
21																												32			
22																															
23									0*																						

FIG. 33.—Perch caught in gill nets set at various depths, Lake Mendota, 1915. The curve indicates the thermocline. All nets used were 1-inch bar mesh. * indicates a net 4 by 50 feet which caught only one-fifth as many perch as the other nets used, which measured 3 by 75 feet. Nets were left in the water about 24 hours. The ice left the lake April 9 to 11; the fall overturn took place October 9 and 10.

One other possibility remained to be tested, however. During the period of stagnation in the lower water the perch might remain on the bottom in the region of the thermocline or spread out over the whole lake to feed on the plankton organisms in the water containing oxygen. The latter alternative seemed improbable from the fact that it is easiest to catch perch near the bottom at any season, but it was decided to perform an experiment to find out. Accordingly, on August 10, 1916, four 1-inch mesh, 3 by 60 feet, gill nets were set north of the University of Wisconsin in Lake Mendota. At this time the thermocline was well established at a depth of 9 meters, and the gaseous content of the water (according to titrations by the Winkler method; Birge and Juday, 1911) at certain depths was as follows: At 18 m.—Oxygen, 0.01 c. c. per liter; carbon dioxide, 10.31 c. c. At 14.5 m.—Oxygen, 0.01 c. c.; carbon dioxide, 4.1 c. c. At 13 m.—Oxygen, 0.02 c. c.; carbon dioxide, 4.17 c. c. At 6.6 m.—Oxygen, 4.49 c. c.; carbon dioxide, 0 c. c. One net was set at 19.2 m. on the bottom; another was set where the water was 19 m. deep, but the net was fastened to eight weighted 11 m. lines, so that it floated just above the thermocline; a third was set on the bottom where the water was 8 to 9.2 m. deep; the fourth was set on the bottom at a depth of 3 m. All of these nets were set at right angles to the shore line and were placed in a straight line from deep to shallow water. They were left in the water three hours (9.45 to 10.30 a. m. to 12.45 to 1.30 p. m.). Nothing but perch was taken in the nets, and the catches were as follows: On bottom at 19.2 m., 0; at a depth of 8 m. above bottom 19 m. deep, 0; on bottom at 8 to 9.2 m., 118 (49 alive, 69 dead; males, 42 dead, 17 alive; females, 27 dead,

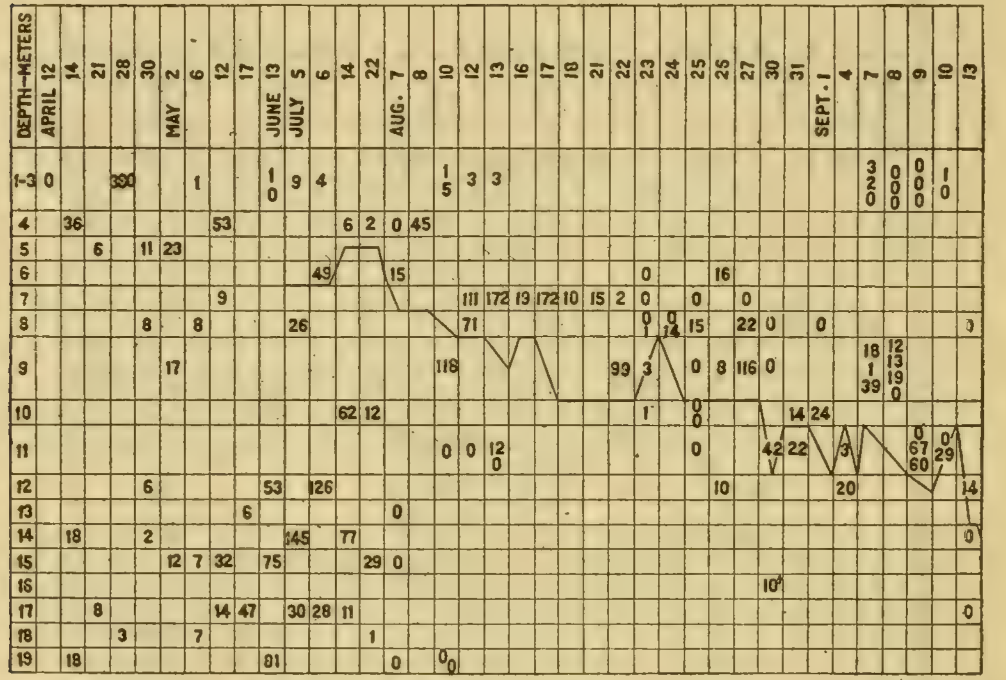

FIG. 34.—Perch caught in 3 by 60 feet, 1-inch bar mesh gill nets, Lake Mendota, 1916. Nets were left in the water for various periods of time, but those set on any particular day were left for the same length of time, and the catches for that day at different depths are therefore comparable. The curve represents the thermocline. The ice left the lake on April 8; the fall overturn occurred October 5 to 10. † indicates 10 perch caught at 16 m. in about 2 minutes while washing net.

32 alive); on bottom at 3 m., 5 (all alive; 3 males, 2 females). This experiment indicates that perch are bottom fishes at all seasons. The observations of Hankinson (1908), Reighard (1915), and Meek (1916), in other lakes make it apparent that this condition is general.

Meek (1916) states that perch are more sluggish in winter. The gill-net and line catches for both lakes support his view (Tables 2 to 5 and 27). The catches in Lake Wingra indicate, however, that cool or stormy weather does not interfere with feeding if food is available. On windy days, when the gill nets caught little, the usual numbers of fish were captured from a drifting boat on hooks. The fishes in this shallow lake were apparently ready to eat if food was present but were unable or unwilling to move about much during storms.

On several occasions schools of perch were observed at the surface. This occurred once at 10 p. m. on Lake Wingra and was observed several times from 5 to 7.30 a. m. in Lake Mendota during the warmer months. As such schools were usually observed during early morning hours, it was thought that there might be a daily migration which would take the perch into shallow water at night and into deep water during the day. Such a migration could not, however, be very extensive, because perch caught at depths of more than 10 m. were apparently unable to make rapid modifications in their swim bladders so as to become adjusted to surface conditions. When kept in shallow aquaria such deep-water perch, though apparently in good condition, often floated belly up at the surface for two or three days.

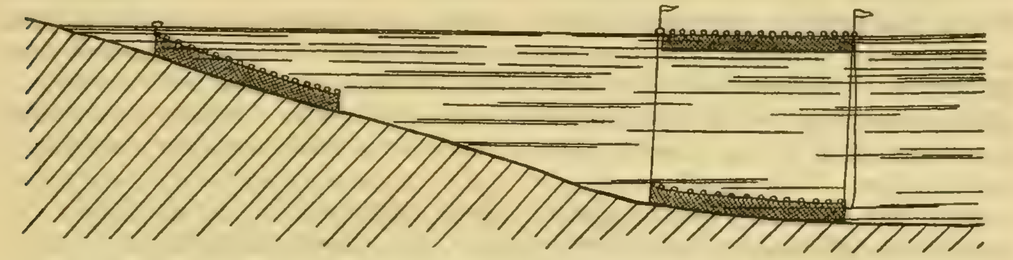

Fig. 35.—Positions of gill nets set to determine the comparative numbers of perch at different depths.

It was possible, however, that there might be rhythmical migrations, a few meters in extent, with the changes accompanying day and night. Gill nets were accordingly set to discover if such were the case. They were arranged to catch fish at the surface and on the bottom, so as to give opportunity for comparing the numbers present in two or more situations, and were examined at the end of 4-hour periods for 24 hours. On August 12, 1916, three nets were set in Lake Mendota (fig. 35). One floated at the surface; another was on the bottom directly beneath it at a depth of 7.5 m. (just above the thermocline); another was inshore from the other two and on the bottom at 2.9 m. The catches for this and two other similar experiments are shown in Tables 28 to 30.

It will be noted—

1. That there were never many perch caught in shallow water near shore.

2. That in the bottom net just above the thermocline the catches in the early morning hours (1 to 3 a. m.) were usually the smallest. For the three experiments the average catches were as follows: From 12 m. to 4 p. m., 43; 4 p. m. to 8 p. m., 56; 8 p. m. to 12 p. m., 37; 12 p. m. to 4 a. m., 12; 4 a. m. to 8 a. m., 41; 8 a. m. to 12 m., 41.

3. That the only time when perch were caught in the surface net was at 5 a. m.

These results indicate that perch migrate from the region of the thermocline toward the surface during the night, but the number of observations is small and should be extended. In the experiment summarized in Table 30, where the deep net was exactly on the thermocline, not a single perch was caught during the early morning hours.

All catches in Tables 28 and 30 marked with an *e* were taken ashore; all others were thrown back as soon as they were removed from the net. It will be noted that, when the fish were not put back, the next catch was not appreciably smaller. The first catch in each experiment should have been larger, if all other conditions were the same, for the nets remained in the water exactly 4 hours. Pulling a net and the removal of the fish occupied from 2 to 25 minutes, which would make the periods of time for the various catches after the first somewhat less than 4 hours. The fact that as many fish were caught during the next 4 hours, when an entire catch was removed from that region of the lake, as when they were put back indicates that, though perch keep to a particular depth, which varies somewhat with the time of day, they do not remain in one locality, but continually swim along the shore.[a]

One other aspect of the migratory activities of perch remains to be considered. This is their habit of swimming in schools. Meek (1916) states that soon after hatching certain species of marine fishes form schools which retain their unity for several years. He also says that schools of fresh-water fishes are much more likely to mix; fishes of different ages, and even of different species, may keep together. Schools of perch have been observed at various times in shallow water in the two lakes under consideration in this paper. These usually consisted of fish of about equal size—large, medium, or small. They have been seen alongshore, among aquatic plants, and in the open lake both at the surface and at a depth of 3 or 4 m. For example, during the latter part of August, 1916, a school of about a thousand young perch remained alongshore in one locality, just north of the University of Wisconsin, for more than a week. Hankinson (1908, 1916) and Reighard (1915) report similar schools of young perch in Michigan lakes. Catches in gill nets also indicate that perch swim in schools when in deep water. A net set in one spot and examined at intervals might catch nothing for several hours and then be filled in a few minutes (Table 30). A similar thing often happened when fishing with a hook and line. Furthermore, a 60-foot gill net might have 50 or 75 perch in one end and not a single individual in the other. All these observations signify that perch swim in schools throughout life.

ENEMIES AND PARASITES.

PREDATORY ENEMIES.

In the Wisconsin lakes perch pay the penalty for exceeding other fishes in abundance by being preyed upon by a number of predacious animals. Among the fishes the pickerel (*Esox lucius*) appears to be the species which most commonly feeds upon perch. During the year 1916 the following records were secured from Lake Mendota:

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[a] During the summer of 1917 additional evidence was secured which supports this view. Nine hundred and sixty-six perch were caught in gill nets at three stations in Lake Mendota. An aluminum tag was fastened to the dorsal fin of each, and they were then returned to the lake. Although fishing with nets was continued for a total of 33 days at the three places, only one of the tagged fishes was caught a second time.

Date.	Length of pickerel (millimeters).	Perch eaten.	
		Number.	Size (millimeters).
April 17	730	1	185
April 25	755	1	200
June 12	164	3	95
August 23	362	1	140
Do	400	1	105

The remains of perch have also been found in largemouth black bass (*Micropterus salmoides*) caught in Lake Mendota. Dogfishes (*Amia calva*) were often caught in gill nets in shallow water, and in many cases they were near perch which had been previously captured in the net. Such occurrences indicate that dogfishes may feed upon perch, but the authors have never found them in the alimentary canal. The gar (*Lepisosteus osseus*), doubtless, also feeds on young perch. Hankinson (1908) found pickerel feeding on perch and also mentions an 8-inch perch as occurring in the wall-eyed pike (*Stizostedion vitreum*). Forbes and Richardson (1908) state that 75 per cent of the food of the lota (*Lota maculosa*) is made up of perch. Reighard (1915) reports perch feeding on each other.

Besides finny enemies, perch are probably often beset by other predators; for instance, water snakes, garter snakes, and bullfrogs may catch the young alongshore. Turtles often eat perch caught in nets, and probably feed upon them when they have a chance under natural conditions.

A. R. Cahn has furnished observations on birds which eat perch. In Wisconsin he has found the following feeding on perch: Herring gull, common tern, black tern, American merganser, red-breasted merganser, great blue heron, green heron, black-crowned night heron, loon, horned grebe. He states that the following also probably eat perch: Double-crested cormorant, white pelican, other species of gulls and grebes, and the bald eagle. Fisher (1893, p. 32) reports the fishhawk as feeding on perch; Eaton (1910, p. 137) mentions the kingfisher. The senior writer on June 10, 1916, saw a crow pick a crappie (*Pomoxis sparoides*) from the surface of Lake Wingra. Though the fish in this instance struggled actively and finally escaped, the crow may at times be more successful in its aquatic forays and capture fishes from the water. Probably such carnivorous mammals as the otter and mink at times capture perch.

Among the predatory animals mentioned the only ones which commonly follow the perch into deep water are the pickerel (Reighard, 1915) and the lota. The latter does not occur in either of the lakes discussed in this paper but is important in the Great Lakes and some other smaller bodies of water. The majority of the perch in Lake Mendota are therefore free from attack by predacious enemies during most of the year, except for an occasional pickerel.

PARASITES.

While the routine weekly examinations of perch were made primarily for the purpose of ascertaining the nature of the food, after March, 1915, a careful record was kept of the presence of parasites. This record is doubtless incomplete; the numbers are too small rather than too large. For example, many of the intestinal distomes were doubtless overlooked, because the food was stripped from the intestines, and they may have remained attached to its wall. The commonest intestinal distome, *Bunodera nodulosa*, lives in the bile ducts and gall bladder during early stages, but no regular examinations were made to discover its presence at seasons when it was not in the intestines. Every parasite observed was not identified as to species, but practically all, if not all, will fall in the list which follows. No routine record was kept of the occurrence of the skin parasite, *Diplostomulum cuticola.*

The results of the routine examinations for parasites are summarized in Tables 31 and 32. Nematodes were never present as intestinal parasites during December; in Lake Mendota they were most abundant in summer; in Lake Wingra, from March to May and from August to November. In Lake Mendota no trematodes were found in the intestines during September, October, and November; and in Lake Wingra none were found at any season. The cysts of larval proteocephalid tapeworms were prevalent in the liver, and often in the peritoneum elsewhere, during every month of the year. Larval proteocephalids were most abundant in the intestine from March to May in Mendota but were irregularly distributed through the year in Wingra. Acanthocephalans were most abundant in spring in both lakes. Leeches and adult tapeworms were uncommon and irregular in their occurrence.

The most striking difference in regard to parasites between the perch of Lake Mendota and those of Lake Wingra is in the complete absence of intestinal trematodes from the latter. This may be due to the absence of a proper intermediate host in Lake Wingra. The following list includes all the parasites known to occur in the perch from Wisconsin lakes:

PROTOZOA.

Henneguya wisconsinensis Mavor and Strasser.—This myxosporidian was first described from specimens taken from the urinary bladder of a male perch caught in Lake Mendota and examined on April 15, 1915. During the present investigations no examinations for this parasite have been made.

CESTOIDEA.

Proteocephalus pearsei La Rue.—Specimens of larval cestodes, cestode larval cysts, and adult tapeworms were sent to Dr. G. R. La Rue, of the University of Michigan, who was kind enough to describe them (1919). One of the larval cysts was found in the body muscles on October 13, 1916.

TREMATODA.

Bunodera luciopercae (O. F. Müller).—This fluke was common in the intestines, particularly in the cæca, in perch collected from Lake Mendota but was absent from those collected from Lake Wingra. It has previously been reported in the perch from this country by Stafford (1904) at Montreal, Canada, and by Marshall and Gilbert (1905) from the lakes near Madison, Wis.

Clinostomum marginatum (Rudolphi).—This trematode was observed twice in the perch from Lake Mendota. On September 25, 1915, a cyst containing a nearly mature specimen was found beneath the skin in the flesh at the base of the tail. On January 10, 1917, the gills of 20 perch, which had been caught at a depth of 17 m., were examined and one small larval cyst was discovered, embedded in a gill filament. These isolated observations, of course, give no idea of the prevalence of this parasite in Wisconsin.

Diplostomulum sp.—This skin parasite was observed now and then in the lakes near Madison and was always more abundant in the young fish than in adults. It was very prevalent in the perch from Oconomowoc Lake. An idea of the difference in infection in perch from two Wisconsin lakes may be gained from the following statistics:

Fourteen perch, collected from Lake Mendota, near the base of Picnic Point, August 24, 1916 (length—maximum, 69; minimum, 52; average, 61 mm.), were infected to the degree shown by the following "number of infected individuals—total number of parasites—average" figures: Tail, 5-5-3.5; fins, 0; head, 8-16-1.1; ventral region, 9-18-1.3; dorsal region, 14-15-1; whole body, 14-55-4.

Thirty-nine individuals collected on July 17 and August 8, 1916, in Oconomowoc Lake (length—maximum, 98; minimum, 35; average, 55.1 mm.),showed: Tail, 25–53–1.3; fins, 24–79–2; head, 26–98–2.5; ventral region, 31–132–3.3; dorsal region, 25–123–3.1; whole body, 38–490–12.9.

(?) *Allocreadium isoporum* Looss.—One specimen, which is apparently referable to this species, was found in the intestine of a perch collected in Oconomowoc Lake, August 14, 1916.

Crepidostomum cornutum (Osborn).—Eight specimens were found in a perch caught in Lake Mendota at a depth of 18 m., January 10, 1918.

ACANTHOCEPHALA.

Neœchinorhynchus cylindratus (Van Cleave).—This was the common acanthocephalan found in perch. Sometimes it occurred in great numbers. In one instance a couple of hundred were found in the intestine of a single perch.

Echinorhynchus thecatus Linton.—One specimen, which is apparently referable to this species, was saved from a perch 60 mm. long caught on August 24, 1916, in a minnow seine east of Picnic Point.

NEMATODA.

Dacnitoides cotylophora Ward.—Specimens of the nematodes from perch intestines were probably of this species.

HIRUDINEA.

Piscicola punctata (Verrill).—This was the species of leech usually found on the perch in the lakes investigated.

Placobdella parasitica (Say).—One individual of this species was found attached to a perch caught in Lake Wingra October 28, 1916. Our thanks are due to Prof. J. P. Moore, who identified it.

INSECTA.

Psephenus sp.—On July 22, 1916, a perch, caught at a depth of 15 m .in Lake Mendota, had a "water penny" attached to its body just behind the right pectoral fin. This beetle larva must, therefore, be recorded as an accidental commensal or parasite.

GENERAL DISCUSSION AND CONCLUSIONS.

The investigations on the perch in the two lakes selected for study have been described, and it is now time to return to the problems it was hoped they would solve: (1) To account for the abundance of perch compared to other species of fish; (2) to determine why perch have a particular maximum size in certain lakes and why they are larger in some lakes than in others; and (3) what effect stagnation has on the activities of fishes.

The perch appears to be more abundant than other species of fish because it is versatile and not too specialized. Though it has certain specificities of behavior, such as the habit of usually feeding on or near the bottom, it is able, more than any other fish with which it is associated, to invade all habitats. It may feed on the enormous quantities of plankton in the pelagic regions; it is at home among aquatic vegetation; and it may grub out the animals embedded in such great numbers in the soft bottom mud or even largely subsist for a time on the mud itself. Its chief advantage over the common shore fishes is in its ability to forsake the shore, with its stores of food dependent chiefly on the aquatic vegetation, and invade the depths of the lakes, where the chief source of food is the soft sedimentary bottom deposits rich in organic constituents.

The perch has rivals in each of the habitats where it seeks food, but it is an able competitor of them all. In shallow waters it may capture mollusca as well as the pumpkinseed, littoral plankton as well as the silversides or bream, insects and their larvæ as well as the bass, crayfishes as well as the dogfish, small minnows as well as the gar. In the open lake the perch's chief competitors for food are the cisco and the white bass, but neither of these fishes excels it in ability to strain plankton from the water. In the deeper regions of lakes the perch must contend with the vegetarian and bottom-feeding sucker, cottid, and carp, and with the predacious pickerel and lota. The sucker, cottid, and carp are real rivals when it comes to bottom feeding, for they are especially able to take advantage of the nourishment in the bottom mud.[a] They are also better protected, by reason of their size, from the attacks of the predacious deep-water fishes; but their large size, on the other hand, limits their numbers, and they can never compare with the perch in this respect. These bottom feeders are limited, however, in times of scarcity or when they are driven into shallow water by stagnant conditions in the depths. They can not then feed as well as the perch in pelagic or littoral regions.

Perch are, then, more abundant in lakes than other kinds of fishes because they are of intermediate size and because they are better able to secure food from all available habitats and at all seasons of the year.

There are probably a number of factors which cause perch to attain a certain characteristic maximum size in different lakes. This is a phenomenon which is not confined to perch alone but has been noted in other fishes. It is apparent, for example, in the ciscoes in various Wisconsin lakes, and has been observed in other localities in various parts of the earth. Petersen and Jensen (1911) state that the plaice in a certain estuary ceased to grow for two-thirds of a year, whereas some which were transplanted quadrupled in size during the same period of time. They believe that the discrepancy in this instance was due to differences in food. The present authors believe that their comparison of the habits of perch and their conditions of life in Lake Wingra and in Lake Mendota have shed some light on the causes for such contrasts, and they feel that they can, at least in part, give specific reasons why the perch are smaller in the former lake.

The shallowness of Lake Wingra is probably the chief cause for the small size of its perch. The limitation of perch to a stratum of water 3 m. in thickness, between the air above and soft muddy bottom below, causes many unfavorable conditions. Winds stir up the whole body of water; thus movement and feeding are often made difficult or impossible. Knauthe (1907) has made the generalization that in two ponds of equal capacity in other ways the quieter one will be the more productive for rearing fish.

On account of the shallowness of the water in Lake Wingra there are wider and more rapid variations in temperature. The water is all warm in summer; there is no possibility of retreat into cool, quiet depths; and consequently the perch in this lake pass through a period in late summer when little food is eaten (Table 22). In winter, the perch in Lake Wingra move about very little and hence feed less than those in Lake Mendota (Tables 2 to 5, 22, and 27; figs. 3 to 5). Though oxygen was always present in quantities sufficient for respiration, many of the fish caught in gill nets in Lake Wingra died during the warmer months, when the water was murky with algæ and other organic or sedimentary products.

The perch in Lake Wingra, on account of the earlier warming of the water, breed before those in Lake Mendota, when the season is less advanced and food is less abundant. They also mature the gonads earlier in the autumn, in part during the hottest weather when food is readily available but when feeding conditions are unfavorable. Perch hatching in Lake Wingra have less desirable conditions for feeding during their growth period.

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[a] The importance of this deposit as a source of food has been pointed out in a masterly way by Petersen and Jensen (1911).

There are two conditions which appear to be more favorable to the perch in Lake Wingra. One of these is the fact that there is abundant oxygen for respiration at all depths during the summer when feeding is active. The other is the entire absence of trematode intestinal parasites. These two factors, however, appear to be of little importance compared with those cited in the preceding paragraphs, which are more favorable in Lake Mendota. The differences between the perch in the two lakes in regard to the constituent elements in the food are probably not important in determining maximum size. As has been stated, the perch in Wingra eat more of insect larvæ and less of Entomostraca than those in Mendota; but there is no reason to believe that such differences would account for the discrepancies in size.

The chief generalization to be made from the comparisons between Lake Wingra and Lake Mendota is that, at least in temperate regions, a deep lake is a far better habitat for most fishes than a shallow one and will usually be more productive. There is no doubt that some fishes, such as the crappie, are peculiarly adapted to shallow-water habitats, as shown by the senior author in a report (1919) compiled from studies, extending through an entire year, of the abundant crappies in Lake Wingra. But though there are such special cases and though more extensive studies in different types of lakes will doubtless bring new facts to light, the authors believe their first statement will, in general, hold good. Of course, a deep lake without suitable breeding grounds and with a scanty fauna would have few fishes, but even under such circumstances it would excel a shallow lake with similar characteristics.

One other problem remains for solution, and, though the results presented in this paper do not solve it, they may help to do so. This is the determination of the factors controlling the productiveness of lakes of various types and sizes. An understanding of this may in time give man the power to control and increase production.

An attempt has been made to gain some idea of the productiveness of Lake Mendota in terms of the total number of perch caught from its waters per year. Daily counts were made of the number of fishermen on the eastern half of the lake from January 8 to February 27, 1917, at 10 a. m. and 3 p. m. At intervals trips were made around the lake to ascertain how long each man had been fishing and the number of perch caught. The number of fishermen averaged 19.1 in the morning and 31 in the afternoon. Their catch per hour averaged 23.6. Estimating that each man counted fished three hours, and that one-fourth of the fishermen (not counted) were on the west end of the lake, the total average catch per day for all fishermen would be 2,358. There is more fishing for perch in winter than in summer. Probably the number of perch caught per day when there is no ice is about one-fourth that during the winter. This means that 2,358 perch are caught per day for four months and 589 per day for eight months. From such speculation it may be estimated that 424,540 perch are caught each year from Lake Mendota. Judging by the other fishes taken in gill nets and by our general knowledge of conditions, it is estimated that the total annual catch of other species by fishermen is about as follows: Pickerel (*Esox lucius*), 2,208; white bass (*Roccus chrysops*), 615; rock bass (*Ambloplites rupestris*), 613; silver bass or crappie

(*Pomoxis sparoides*), 183; largemouth black bass (*Micropterus salmoides*), 305; pumpkinseed (*Eupomotis gibbosus*), 428; bluegill (*Lepomis incisor*), 1,238.

This gives a rough approximation of the number of food fishes caught in Lake Mendota each year and may serve as a standard for lakes of similar size, depth, and situation. The old fishermen claim that many more fish were caught 15 years ago and state that a single man sometimes secured over 800 perch in a day. At present the usual catch of a professional fisherman, fishing through the ice with a line and two hooks, is from 200 to 400 per day.

Lake Wingra not only has smaller perch, but fewer of them. This is clear from the catch per hour in gill nets (Tables 2 to 5; figs. 3 to 5). The reasons for lesser size have already been discussed, and apparently the same reasons set a smaller limit to numbers. The differences between the sizes and numbers of perch in the two lakes are due to variations which interfere with growth and allow fewer individuals to survive in Lake Wingra.

SUMMARY.

1. The habits of perch in a small, shallow, and muddy lake were compared with those of perch in a neighboring large, deep, and clean lake. Perch were the most abundant fishes in both, but, in proportion to the size of the lake, there were more in the larger lake.

2. The perch is a versatile feeder but usually gets its food on or near the bottom. The percentage by volume of the foods eaten by 1,147 adults was as follows: Chironomid larvæ, 25.2; cladocerans, 22.1; Corethra larvæ, 6.4; silt and bottom débris, 6; chironomid pupæ, 5.9; fish, 5.2; amphipods, 3.6; Sialis larvæ, 3.4; caddisfly larvæ, 2.1; oligochætes, 1.5; crayfishes, 1.5; odonate nymphs, 1.4; clams, 1.2; algæ, 1.2; snails, 1.1; ephemerid nymphs, 0.9; calcium carbonate crystals, 0.5; leeches, 0.4; hemipterous adults, 0.3; mites, 0.3; chironomid adults, 0.2; Corethra adults, 0.2; Corethra pupæ, 0.2; copepods, 0.1; ostracods, 0.09.

3. There are more or less marked seasonal variations in all constituents of the perch's food. In general, foods are eaten in proportion to their abundance and availability; but this is not always the case.

4. An adult perch eats about 7 per cent of its own weight each day. Digestion is three times more rapid in summer than in winter.

5. Perch do not take any abundant food but select certain things. There are daily and seasonal variations. Individuals feeding in shallow water eat a greater variety than those from greater depths. Perch contain food which is available at the depths where they are caught, which indicates that extensive vertical migrations are infrequent.

6. Food varies with age. During youth there is a change from Cyclops and other entomostracans to Hyalella and insect larvæ. At the end of the first summer the food of young perch is much like that of adults.

7. As judged by the rate of increase in young perch when fed on a single food the following varieties rank in the order given, the best being first: Earthworms, entomostracans, chironomid larvæ, amphipods, fish, small amounts of various foods, liver and flour, adult insects.

8. In the small lake investigated insects were the most important constituent of the food. In the larger lakes insects and entomostracans were equally important.

9. Compared with the crappie, the perch eats a greater variety and shows other specificities of behavior.

10. Though perch are able to recognize the proportions of oxygen and carbon dioxide in water, they enter regions where conditions are unfavorable for respiration and may remain in oxygen-free water for as much as two hours without dying. When in water without oxygen perch use part of the oxygen in the swim bladder.

11. Perch may become sexually mature in two years. In the smaller lake investigated they generally become mature when of much smaller size than do those in the larger lake.

12. During the spawning season the males come into shallow water and remain for some time. The females remain on the spawning grounds only long enough to breed.

13. Except during the spawning season and when the deeper water is stagnant, most of the perch in the large lake remain in deep water through the year. In the smaller lake similar migrations take place.

14. There appears to be an upward migration at night.

15. Perch swim more or less in schools throughout the year and apparently do not remain in one locality but move along the shore.

16. Perch have many predacious enemies. The pickerel and lota are important.

17. Perch are very generally infected with parasites. Those in the two lakes investigated contained cestodes and cestode larvæ (one or more species), trematodes (5), acanthocephalans (2), nematodes (1). Leeches and an insect larva were found on the outside of the body.

18. Perch are more abundant in inland lakes than other species because they are more versatile.

19. Large inland lakes will generally contain more fishes per unit of volume than those of smaller size.

20. Judging by the data presented in this paper the reason why the fishes in certain inland lakes attain a rather small maximum size is because there are various adverse conditions which prevent growth. In the present instance food does not appear to be as important as other factors, such as shallowness, exposure to wind, etc.

TABLES.

Table 1.—Comparison of Lake Mendota and Lake Wingra, Each 258.8 M. (849 Feet) Above Sea Level.

Lake.	Length.		Breadth.		Area.		Maximum depth.		Mean depth.		Shore line.	
	Kilometers.	Miles.	Kilometers.	Miles.	Square kilometers.	Square miles.	Meters.	Feet.	Meters.	Feet.	Kilometers.	Miles.
Mendota	9.5	5.8	7.4	4.5	39.4	15.2	25.6	84	12.1	39.6	32.4	20.1
Wingra	2.6	1.6	1.4	.8	2.17	.79	4.25	14	1.6	5.3	7.3	4.5

TABLE 2.—TOTAL AND COMPARATIVE NUMBER OF PERCH CAUGHT IN GILL NETS SET AT VARIOUS DEPTHS IN LAKE MENDOTA, JULY 2 TO DEC. 14, 1915, WITH NOTES ON THE AMOUNTS OF OXYGEN AND CARBON DIOXIDE PRESENT.[a]

Date.	Depth net set (meters).	Cubic centimeters of gases per liter.		Number of perch caught.						
		O.	CO_2.	Alive.	Dead.	Total.	Average per hour at—			
							0–5 m.	5–10 m.	10–15 m.	15–24 m.
June 5	3.0					23				
June 6	10.0					89				
	11.0					69				
	12.0					88				
June 19	4.0					6				
June 26	4.0					4				
	10.0					32				
July 3	9.5					176		7.3		
	12.9					267			11.1	
July 10	3.5			11	2	13	0.5			
	16.5					203				8.4
	18.3					175				7.2
July 17	3.0			3	0	3	.1			
	18.5	0.96	6.22	30	59	89				3.7
July 24	4.0			39	3	42				
	15.5	.36	6.76	16	89	105				4.3
	18.5	.16	7.65	1	6	7				.3
July 31	3.0			1	0	1				
	7.1			112	3	115				
	18.6	.55	4.59	0	0	0				
	[b] 23.1	.1	5.1	0	0	0				
Aug. 7	5.0			25	1	26				
	11.8	4.62	0.0	32	148	180			7.5	
	13.0	3.14	0.0	32	55	87			3.6	
	[b] 16.3	.06	4.74	0	4	4				.1
Aug. 14	12.0	.03	0.2	10	199	209			8.7	
	13.6	.06	4.13	9	171	180			7.5	
	15.6	.04	4.89	9	37	46				2.0
	[b] 18.5	.04	4.74	0	2	2				.08
Aug. 21	4.0			35	5	40	1.6			
Aug. 28	4.0			30	0	30	1.2			
Sept. 4	4.0			33	1	34	1.4			
	10.0	5.02	0.0	83	13	96		4.0		
	12.3	1.77	3.31	102	26	138			5.7	
	[b] 18.5	.00	11.92	1	1	2				.08
Sept. 11	4.0			9	1	10	.4			
Sept. 18	[b] 4.0			4	1	5	.2			
Sept. 25	[b] 3.5			1	0	1				
	14.5	2.32	6.29	93	82	175			7.3	
	16.7	.04	5.67	6	13	19				.8
	18.6	.008	7.14	1	1	2				.08
Oct. 2	5.5			62	4	66		2.5		
Oct. 9	[b] 4.5			0	0	0				
	14.3	6.60	.51	89	0	89			3.7	
	16.7	6.63	1.31	201	0	201				8.3
	19.0	6.86	.25	167	0	167				7.0
Oct. 16	11.7			31	0	31			1.3	
Oct. 23	19.0			54	0	54				2.2
Oct. 30	6.0			12	0	12		.5		
Nov. 6	3.5			0	0	0				
	18.5			94	0	94				4.0
	[b] 18.5			17	0	17				.7
Nov. 13	[b] 13.0			20	0	20			.8	
	13.0			94	0	94			4.0	
Nov. 20	4.0			0	0	0				
	3.0			0	0	0				
Nov. 22	14.6			23	0	23			.5	
Nov. 27	3.5			7	0	7	.2			
	3.5			1	0	1				
Dec. 4	16.3			41	0	41				1.7
	21.0			32	0	32				1.3
Dec. 9	3.5			2	0	2				
Dec. 11	12.5			47	0	47			2.0	
Dec. 14	3.5			1	0	1				

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[a] All nets used were 1-inch bar mesh, measuring 3 by 75 feet, except those marked [b], which were ¾-inch bar mesh, measuring 4 by 50 feet. For some reason the latter caught only one-fifth as many perch as the former, as is demonstrated by the catches on Nov. 6 and 13.

[b] See note under [a].

TABLE 3.—PERCH CAUGHT PER HOUR AND PER DAY IN GILL NETS, LAKE MENDOTA, 1916.

Date.	Depth set (meters).	Cubic centimeters of gases per liter.		Gill nets.			Number of perch caught.		
		CO_2.	O.	Time set.	Time pulled.	Hours in water.	Total.	Average per hour.	Average per 24 hours.
Apr. 12	1 - 3	......	......	......	......	......	0	......	......
Apr. 14	19	......	......	......	......	24	18	0.7	......
	14.5	......	......	......	......	24	18	.7	......
	3.7	......	......	......	......	24	36	1.5	......
Apr. 21	17.3	......	......	5 p.m.	7 a.m.	14	8	.5	12
	5	......	......	5 p.m.	7 a.m.	14	6	.4	9.6
Apr. 28	[a]18.2	......	......	4.45 p.m.	6.30 a.m.	13.7	14	1.0	24.0
	18.2	......	......	4.45 p.m.	6.30 a.m.	14	3	.2	4.8
	[a]3 - 1.8	......	......	4.45 p.m.	6.30 a.m.	14	163	11.6	278.4
	3 - 1.8	......	......	4.45 p.m.	6.30 a.m.	14	380	27.0	648.0
Apr. 30	14.5	......	......	6.50 a.m.	10.05 a.m.	3.2	2	.15	3.6
	12.5	......	......	7.05 a.m.	10.14 a.m.	3.1	6	.3	7.2
	8.5	......	......	7.16 a.m.	10.20 a.m.	3	8	.5	12.0
	5	......	......	7.25 a.m.	10.32 a.m.	3.2	11	3.6	86.4
May 2	15	......	......	1.53 p.m.	4.53 p.m.	3	12	4.0	96.0
	9.5	......	......	2.08 p.m.	5.08 p.m.	3	17	5.1	134.4
	4.7- 4.5	......	......	2.18 p.m.	5.20 p.m.	3	23	7.6	182.4
	[a]4.5- 4.1	......	......	2.22 p.m.	5.16 p.m.	3.1	18	6.0	144.0
May 6	18	......	......	6.38 a.m.	9.38 a.m.	3	7	2.3	55.2
	15	......	......	6.51 a.m.	9.51 a.m.	3	7	2.3	55.2
	7.7	......	......	7.00 a.m.	8.00 a.m.	1	8	8	192
	1.5- 3	......	......	7.14 a.m.	9.10 a.m.	2	1	.5	12.0
May 12	17	......	......	5.12 a.m.	8.12 a.m.	3	14	4.6	110.4
	15	......	......	5.20 a.m.	8.21 a.m.	3	32	10.6	254.4
	7	......	......	5.31 a.m.	8.36 a.m.	3	9	3.0	72.0
	4 - 3.1	......	......	5.41 a.m.	8.42 a.m.	3	53	17.6	422.4
May 17	17	......	......	12.01 a.m.	2.00 a.m.	2	47	23.5	364.0
	13	......	......	12.13 a.m.	2.13 a.m.	2	6	3.0	72.0
June 13	19	......	......	8.19 a.m.	11.19 a.m.	3	81	27.0	648.0
	15.5	......	......	8.33 a.m.	11.35 a.m.	3	75	25.0	600.0
	12	......	......	8.43 a.m.	11.44 a.m.	3	53	17.6	422.4
	2.5- 3	......	......	8.57 a.m.	11.57 a.m.	3	1	.3	7.2
	3 - 3.5	......	......	9.01 a.m.	12.05 a.m.	3	0	0	0
July 5	17	......	......	10.42 a.m.	1.53 p.m.	3.1	30	9.6	230.4
	14	......	......	10.51 a.m.	2.00 p.m.	3.1	145	45.8	1,099.2
	8.5	......	......	11.07 a.m.	2.05 p.m.	3	26	8.6	206.2
	3 - 3.6	......	......	11.20 a.m.	2.11 p.m.	2.8	9	3.2	76.8
July 6	17	......	......	11.00 a.m.	1.46 p.m.	2.7	28	10.1	242.4
	12	......	......	11.10 a.m.	1.56 p.m.	2.7	126	40.5	972
	6.3	......	......	11.20 a.m.	2.03 p.m.	2.7	49	17.8	427.2
	3.1	......	......	11.30 a.m.	2.10 p.m.	2.6	4	1.4	33.6
July 14	17	5.944	1.601	8.35 a.m.	10.35 a.m.	2.0	11	5.5	132.0
	14.3	4.544	3.835	9.08 a.m.	11.08 a.m.	2	77	38.5	924.0
	9.6	3.527	8.131	9.48 a.m.	11.48 a.m.	2	62	31.0	744.0
	4.1	......	......	10.14 a.m.	12.14 p.m.	2	6	2.0	48.0
July 22	18.3	5.234	.123	7.27 a.m.	9.33 a.m.	2.1	1	.5	12.0
	15	4.280	.242	8.14 a.m.	10.14 a.m.	2.0	29	14.5	348.0
	10.5	4.125	1.778	8.44 a.m.	10.44 a.m.	2.0	12	6.0	144.0
	4.5	......	......	9.10 a.m.	11.10 a.m.	2	2	1.0	24.0
Aug. 7	18.6	10.314	.015	8.45 a.m.	10.45 a.m.	2	0	0	0.0
	15.2	4.125	.015	9.15 a.m.	11.18 a.m.	2	0	0	0.0
	13.3	4.177	.024	9.43 a.m.	11.44 a.m.	2	0	0	0
	6.3	0.0	4.493	9.30 a.m.	11.35 a.m.	2	15	7.5	180.0
	3.6	......	......	11.53 a.m.	1.53 p.m.	2	0	0	0
Aug. 8	3.8- 3.3	......	......	......	......	[b]4	45	11.2	268.8
	[a]3.8- 3.3	......	......	......	......	[b]4	122	30.5	732
Aug. 10	19	......	......	9.45 a.m.	12.45 p.m.	3	0	0	0
	19.2	......	......	10.00 a.m.	1.02 p.m.	3	0	0	0
	8 - 9.2	......	......	10.18 a.m.	1.18 p.m.	3	118	39.3	943.2
	3	......	......	10.30 a.m.	1.40 p.m.	3	5	1.6	38.4
	3.1- 2.5	......	......	8.35 a.m.	12.33 p.m.	4	1	.25	6
	11	......	......	9.00 a.m.	1.00 p.m.	4.0	0	0	0
Aug. 12	7.7- 7.2	......	......	9.12 a.m.	1.18 p.m.	4.1	111	27.0	648
	2.5- 3.1	......	......	12.33 p.m.	4.30 p.m.	4.0	3	.7	16.8
	11	......	......	5.00 p.m.	9.10 p.m.	4.1	0	0	0
	7.2- 7.7	......	......	5.18 p.m.	9.18 p.m.	4.0	71	17.7	424.8
Aug. 13	2.5- 3.1	......	......	9.00 p.m.	1.20 a.m.	4.3	1	.2	4.8
	11	......	......	9.10 p.m.	1.32 a.m.	4.3	0	0	0
	7.2- 7.7	......	......	9.18 p.m.	1.43 a.m.	4.5	24	5.3	127.2
	2.5- 3.1	......	......	1.20 a.m.	5.00 a.m.	3.6	1	.3	7.2
	11	......	......	1.32 a.m.	5.10 a.m.	4.2	12	2.8	67.2
	7.2- 7.7	......	......	1.43 a.m.	5.18 a.m.	3.5	72	20.5	492.0
	2.5- 3.1	......	......	5.00 a.m.	8.30 a.m.	3.5	1	.2	4.8
	11	......	......	5.10 a.m.	9.00 a.m.	3.8	0	0	0
	7.2- 7.7	......	......	5.18 a.m.	9.18 a.m.	4.0	76	19	456

[a] All nets marked with this sign were ¾-inch mesh, bar measure, 3 by 75 feet. All other nets were 1-inch mesh, 3 by 60 feet.

[b] Nets set in Catfish Bay.

TABLE 3.—PERCH CAUGHT PER HOUR AND PER DAY IN GILL NETS, LAKE MENDOTA, 1916—Continued.

Date.	Depth set (meters).	Cubic centimeters of gases per liter.		Gill nets.			Number of perch caught.		
		CO_2.	O.	Time set.	Time pulled.	Hours in water.	Total.	Average per hour.	Average per 24 hours.
Aug. 16	7.5-6.5			8.15 a. m.	9.40 a. m.	1.5	19	12.6	302.4
Aug. 17	6-8			8.15 a. m.	9.30 a. m.	1.2	172	137.6	3,442.4
Aug. 18	6.5-7			8.15 a. m.	9.15 a. m.	1	10	10.0	240
Aug. 21	6.5-7.7			8.10 a. m.	8.35 a. m.	.5	15	36.0	864
Aug. 22	6.5-7			8.00 a. m.	10.20 a. m.	2.3	2	.8	19.2
	9			10.40 a. m.	12.35 p. m.	2.0	99	49.5	988.0
Aug. 23	8-7			8.00 a. m.	8.50 a. m.	.8	0	0	0
	9			8.55 a. m.	9.47 a. m.	1.8	3	1.6	38.4
	10			9.53 a. m.	10.23 a. m.	.75	1	1.3	31.2
	6.5-6			12.30 p. m.	1.30 p. m.	1.0	0	0	0
	8.2			1.35 p. m.	2.35 p. m.	1.0	1	1	24.0
	8.5			2.40 p. m.	3.30 p. m.	.8	0	0	0
Aug. 24	7.5			8.15 a. m.	9.00 a. m.	.75	14	18.6	446.4
	7			8.25 a. m.	9.15 a. m.	.8	0	0	0
Aug. 25	8.5-7			8.00 a. m.	9.28 a. m.	1.5	0	0	0
	7.5			8.10 a. m.	9.23 a. m.	1.2	0	0	0
	7-8.5			8.20 a. m.	9.35 a. m.	1.2	0	0	0
	11.5-10.5	4.950	.09	9.40 a. m.	10.30 a. m.	.8	0	0	0
	10-7.5			9.44 a. m.	10.33 a. m.	.8	0	0	0
	7.5-6.2			9.47 a. m.	10.36 a. m.	.8	0	0	0
	10-9			10.40 a. m.	12.00 m.	1.3	0	0	0
	7.5-11			12.10 p. m.	2.00 p. m.	1.2	15	12.5	150
Aug. 26	12	4.383	.049	6.10 a. m.	7.35 a. m.	1.4	10	7.1	170.4
	9			6.10 a. m.	7.30 a. m.	1.3	8	6.1	146.4
	6			6.10 a. m.	7.25 a. m.	1.2	16	13.3	212.8
Aug. 27	9			6.15 a. m.	7.35 a. m.	1.3	116	89.2	1,140.8
	8			6.14 a. m.	7.55 a. m.	1.6	22	13.8	331.2
	7			6.12 a. m.	8.04 a. m.	1.8	0	0	0
Aug. 30	9.5-8.3			6.23 a. m.	7.04 a. m.	.66	0	0	0
	8.3-7.3			6.29 a. m.	7.08 a. m.	.66	0	0	0
	11.2			7.20 a. m.	7.58 a. m.	.66	42	63	1,512
Aug. 31	10.8-11.2			6.22 a. m.	7.30 a. m.	1.16	14	12	248
	11.2-11.5			6.25 a. m.	7.25 a. m.	1.0	22	22	528
Sept. 1	8			6.24 a. m.	7.30 a. m.	1.1	0	0	0
	10			7.35 a. m.	8.44 a. m.	1.16	24	20.6	494.4
Sept. 4	11.5-11.6			6.30 a. m.	7.45 a. m.	1.25	3	2.4	57.6
	11.6-11.7			6.34 a. m.	7.38 a. m.	1	20	20	480
Sept. 7	9.5			9.43 a. m.	1.43 p. m.	4.0	1	.2	4.8
	(a)			9.49 a. m.	1.52 p. m.	4.0	0	0	0
	3-2.6			10.10 a. m.	2.04 p. m.	4.0	3	.7	16.8
	9.5			1.45 p. m.	5.37 p. m.	4.8	18	9.8	235.2
	(a)			1.52 p. m.	5.48 p. m.	4.0	0	0	0
	3-2.6			2.06 p. m.	5.55 p. m.	3.8	2	.4	9.6
	9.5			5.43 p. m.	9.47 p. m.	4.0	39	9.7	232.8
	(a)			5.48 p. m.	10.08 p. m.	4.6	0	0	0
	3-2.6			5.55 p. m.	10.18 p. m.	4.3	0	0	0
Sept. 8	9.5			10.06 p. m.	1.47 a. m.	3.6	12	3.[illegible]	76.8
	(a)			10.10 p. m.	1.44 a. m.	3.5	0	0	0
	3-2.6			10.20 p. m.	2.13 a. m.	3.9	0	0	0.2
	9.5			1.45 a. m.	5.38 a. m.	3.9	13	3.3	79.2
	(a)			2.05 a. m.	5.48 a. m.	3.7	0	0	0
	3-2.6			2.15 a. m.	6.03 a. m.	3.8	0	0	0
	9.5			5.41 a. m.	9.43 a. m.	4.0	19	4.7	112.8
	(a)			5.50 a. m.	9.55 a. m.	4.1	0	0	0
	3-2.6			6.05 a. m.	10.10 a. m.	4.1	0	0	0
	9.5			9.50 a. m.	1.43 p. m.	3.9	0	0	0
Sept. 9	11-11.5			11.15 a. m.	3.07 p. m.	3.9	60	15.3	367.2
	(a)			11.25 a. m.	3.25 p. m.	4.0	0	0	0
	3.1-2.3			11.45 a. m.	4.00 p. m.	4.3	0	0	0
	11			3.25 p. m.	7.15 p. m.	3.16	67	21.1	506.4
	(a)			3.26 p. m.	7.33 p. m.	4.1	0	0	0
	3.2			4.02 p. m.	7.42 p. m.	3.6	0	0	0
	11			7.30 p. m.	11.15 p. m.	3.75	0	0	0
	(a)			7.35 p. m.	11.20 p. m.	3.75	0	0	0
	3.2			7.45 p. m.	11.32 p. m.	3.75	0	0	0
Sept. 10	11			11.17 p. m.	3.06 a. m.	3.8	0	0	0
	(a)			3.12 a. m.	7.06 a. m.	3.9	39	10	240
	(a)			3.17 a. m.	7.20 a. m.	4.0	1	.2	4.8
	3.2			3.29 a. m.	7.37 a. m.	4.1	0	0	0
	11			7.17 a. m.	11.15 a. m.	4.0	29	7.[illegible]	172.8
	(a)			7.23 a. m.	11.23 a. m.	4.0	0	0	0
	3.2			7.38 a. m.	11.45 a. m.	4.1	1	.2	4.8
Sept. 13	17.5			1.55 p. m.	3.25 p. m.	1.5	0	0	0
	14.5			2.10 p. m.	3.40 p. m.	1.5	0	0	0
	12.1			2.19 p. m.	3.49 p. m.	1.5	14	9.3	223.2
	8.7-7.5			2.27 p. m.	3.57 p. m.	1.5	0	0	0

[a] Surface.

TABLE 4.—FISHES CAUGHT PER HOUR IN GILL NETS, LAKE WINGRA, 1916.[a]

Date.	Temperature (degrees centigrade).	Gill nets.			Perca flavescens.	Esox lucius.	Lepomis incisor.	Pomoxis sparoides.	Lepisosteus osseus.	Micropterus dolomieu.	Micropterus salmoides.	Abramis crysoleucas.	Cyprinus carpio.	Eupomotis gibbosus.	Amia calva.	Ameiurus nebulosus.
		Depth set (meters).	Size mesh (inches).	Hours in water.												
Apr. 8	......	2	¾	4	13.7	0	0	0	0	0	0	0	0	0	0	0
		2	1	4	.7	.5	0	0	0	0	0	0	0	0	0	0
		2	2	4	0	0	0	0	0	0	0	0	0	0	0	0
		2	1	2.2	15	0	0	0	0	0	0	0	0	0	0	0
		2	2	2.2	0	1	0	0	0	0	0	0	0	0	0	0
Apr. 14	......	2	¾ and 1	.5	16	0	0	0	0	0	0	0	0	0	0	0
Apr. 20	10.6	.7	¾	1.3	17.3	0	0	0	0	0	0	0	0	0	0	0
		1	1½	4.2	0	1.3	2	1.3	0	.6	0	0	0	0	0	0
		.7	2	4.2	0	0	0	0	0	0	0	0	0	0	0	0
		1	1	4.2	.9	4	4	0	0	0	0	0	0	0	0	0
Apr. 22	......	3	1½	.2	0	4	0	0	0	0	0	0	0	0	0	0
		1.5	¾	1.1	15	0	0	0	0	0	0	11	0	0	0	0
		1	1½	1.6	0	0	0	0	0	0	0	0	0	0	0	0
		1	1	4.6	0	0	0	0	0	0	0	0	0	0	0	0
		1.5	1½	3	0	3	.6	1.6	0	0	.6	0	0	0	0	0
		1.5	¾	3.5	0	0	0	0	0	0	.1	0	0	0	0	0
		1.5	1	3.5	.9	0	.5	0	0	0	0	0	.3	0	0	0
		1.5	1	3.5	0	0	0	0	0	0	0	0	0	0	0	0
Apr. 29	......	2	1	1.4	0	0	0	0	0	0	0	0	0	0	0	0
		2	1½	.5	0	0	0	0	0	0	0	0	0	0	0	0
		1	¾	1.6	5.6	.8	0	0	0	0	0	0	0	0	0	0
		2	1	2.3	0	0	0	0	0	0	0	0	0	0	0	0
		2	1½	2.1	0	0	0	0	0	0	0	0	0	.5	0	0
		2	¾	2.1	0	0	0	0	0	0	0	0	0	0	0	0
		1.5	1½	.4	0	0	0	0	0	0	4	0	0	2	0	0
		1.5	1	.4	0	0	2	0	0	0	0	0	0	0	0	0
		1	1½	1.2	0	0	0	0	0	0	0	0	0	0	0	0
		1	1	1.2	0	0	0	0	0	0	0	0	0	0	0	0
		1.5	1½	1.2	0	0	0	0	0	0	0	0	0	0	0	0
		1.2	1	1.2	0	0	0	0	0	0	0	0	0	0	0	0
May 6	......	1	¾	3.1	13.7	0	.3	0	0	0	0	1.1	0	.3	.3	0
		1	1	3.2	0	0	.3	0	0	0	0	.3	0	0	.3	0
		1	1½	3.5	0	0	0	.3	0	0	0	0	0	0	.5	0
		1	1	.7	5.2	0	1.2	0	0	0	0	0	0	0	0	0
		1	1½	1.7	0	0	0	0	0	0	0	0	0	0	0	0
		1.5	1½	.5	0	0	0	0	0	0	0	0	0	0	0	0
		1.5	1	1	0	0	0	0	0	0	0	0	0	0	0	0
		1.5	1	1	0	0	0	0	0	0	0	0	0	0	0	0
		1.5	1½	1	0	0	0	2	0	0	0	0	0	0	0	0
		1.5	1	.6	0	0	0	0	0	0	0	0	0	0	0	0
		1.5	1½	.6	0	0	0	0	0	0	0	0	0	0	0	0
May 13	16	2	1½	2.3	0	0	0	0	0	0	0	0	0	0	0	0
		2.5	1	3.5	0	0	0	0	0	0	0	0	0	0	0	0
		2	¾	2	6.5	0	0	0	0	0	0	0	0	0	0	0
		1	1	1.3	0	1	0	1	0	0	0	0	0	0	0	0
		1	1½	1	0	0	0	0	0	0	0	0	0	0	2	0
		1	1½	1.5	0	0	0	0	0	0	0	0	0	0	0	0
		1	1	1.3	7.1	0	0	.8	0	0	0	0	0	0	0	0
		1	1½	1.3	0	0	0	1	0	0	0	0	1	0	0	0
May 20	......	1	1½	1.7	0	0	0	0	0	0	0	0	0	0	0	0
		1	1½	.5	0	0	0	2	0	0	0	0	0	0	0	2
		1.5	1½	.3	0	0	0	0	0	0	0	0	0	0	0	0
		1.5	1½	1.3	0	0	0	0	0	0	0	0	0	0	0	0
		1	1	1.0	0	0	0	0	0	0	0	0	0	0	0	0
		1	1	2	0	0	0	0	0	0	0	0	0	1	0	0
		1.5	¾	1	16	0	0	0	0	0	0	0	0	0	0	0
		1.5	¾	.5	10	0	0	0	0	0	0	5	0	1	0	0
		1.5	¾	1	13	0	0	4	0	0	0	0	0	1	0	0
May 27	26	1	1½	1.5	0	0	0	0	0	0	0	0	0	0	0	0
		1	1½	1.3	0	0	0	0	0	0	1.3	0	0	0	0	0
		1	1½	1.5	0	.6	.6	.6	0	0	1.3	0	0	0	0	0
		1	1	1.5	0	0	1.3	0	0	0	0	0	.6	0	0	0
		1	1	1.5	0	0	1.3	0	0	0	.6	0	0	0	.6	0
		1	1	1.5	1.3	0	0	0	0	0	0	0	.6	0	0	0
		1	1	2.5	0	0	0	0	0	0	0	0	0	0	0	0
		1	¾	1.6	37.8	0	.6	0	0	0	0	0	0	0	0	0
June 3	......	1	¾	1	21	0	2	1	0	0	0	0	0	1	1	0
		1	¾	1.2	8.8	0	.8	0	0	0	0	0	0	0	0	0
		1	¾	.3	12	0	0	0	0	0	0	0	0	0	2	2
		1	¾	.3	9	0	4	0	0	0	0	0	0	0	0	0
		1	1	1.1	0	0	0	0	0	0	0	0	0	0	0	0
		1	1	.5	0	0	0	0	0	0	0	0	0	0	0	0
		1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
		1	1½	.7	0	0	0	0	0	0	0	0	6.4	1.2	1.2	0
		1	1½	1.3	0	0	0	0	0	0	0	0	5.6	.8	0	2.4
		1	1½	1	0	0	0	0	0	0	0	0	0	0	0	0
		1	¾	.8	1.2	0	0	0	0	0	1.2	0	0	0	0	0
		1	1	.6	0	0	0	0	0	1.5	0	0	0	0	0	0

[a] In all nets the mesh sizes were bar measure. The 1-inch mesh nets were 60 feet long; all others, 75 feet long.

TABLE 4.—FISHES CAUGHT PER HOUR IN GILL NETS, LAKE WINGRA, 1916—Continued.

Date.	Temperature (degrees centigrade).	Gill nets.			Perca flavescens.	Esox lucius.	Lepomis incisor.	Pomoxis sparoides.	Lepisosteus osseus.	Micropterus dolomieu.	Micropterus salmoides.	Abramis crysoleucas.	Cyprinus carpio.	Eupomotis gibbosus.	Amia calva.	Ameiurus nebulosus.
		Depth set (meters).	Size mesh (inches).	Hours in water.												
June 10	20.5	2	1½	2.2	0	0	0	.4	0	0	0	0	0	0	0	0
		1	1	1	0	0	1	0	0	0	0	0	0	0	0	0
		1.5	¾	.7	8	0	0	0	0	1.2	0	5.2	0	0	0	0
		1.5	¾	.5	8	0	0	0	0	0	0	8	0	0	0	0
June 17	......	1	¾	1.3	8.8	0	0	.8	0	0	0	0	0	.8	0	0
		1	¾	2	10.5	0	0	0	0	0	0	0	0	0	.5	0
		1.5	1	1.1	0	0	0	0	0	0	0	0	0	0	0	0
		1.5	1	2.1	0	0	1.4	.4	0	0	0	0	0	0	0	0
		1.5	1½	1	0	0	0	0	0	0	0	0	0	0	1	0
		1.5	1½	2.3	0	0	0	0	0	0	0	0	0	0	0	0
		1.5	1	1.5	0	0	0	0	0	0	0	0	0	0	0	0
		1.5	1	1.5	0	0	0	0	0	0	0	0	0	1.3	0	0
		1.5	1	1.5	0	0	0	0	0	0	0	0	0	0	0	0
		1.5	1	.7	0	0	0	0	0	0	0	0	0	0	0	0
		1.5	1½	.5	0	0	0	0	0	0	0	0	0	0	0	0
		1.5	1½	1.7	0	0	0	0	0	0	0	0	0	0	0	0
		1.5	1½	1.5	0	0	0	0	0	0	0	0	0	0	0	0
July 22	30	1.8	1½	2.1	0	0	.8	0	0	0	0	0	0	0	0	0
		2.4	1	2.2	.7	0	0	0	0	0	0	0	0	0	0	0
		3.1	¾	2	39	0	0	0	0	0	0	0	0	0	0	0
July 26	29.4	2.4	¾	1.8	8.2	0	0	0	0	0	0	0	0	0	0	0
		3.1	1	2.1	0	0	0	0	0	0	0	0	0	0	0	0
		3.7	1½	2.3	0	0	0	0	0	0	.6	0	0	0	0	0
		3.1	¾	1.6	1.2	0	0	0	0	0	0	0	0	0	0	0
		2.4	1	1.6	1.2	0	0	0	0	0	0	0	0	0	0	0
		2.2	1½	1.6	0	0	0	0	0	0	0	0	0	0	0	0
Aug. 5	......	2.7	¾	2.8	2.9	0	0	0	0	0	0	0	0	0	0	0
		2.7	1	2.8	0	0	0	0	.3	0	0	0	0	0	0	0
		2.7	1½	2.8	0	0	.3	.7	0	0	0	0	0	0	0	0
Aug. 11	26	2.9	¾	1.5	0	0	.6	.6	0	0	.6	0	0	0	0	0
		2.9	1	1.4	0	0	0	0	0	0	0	0	0	0	0	0
		3	1½	1.3	0	0	.7	0	.7	0	0	0	0	.7	0	0
		3.5	¾	1.7	0	0	0	0	0	0	0	0	0	.5	0	0
		3.3	1	1.7	0	0	0	0	0	0	0	0	0	0	0	0
		3.1	1½	1.5	0	0	0	0	0	0	0	0	0	1.2	0	0
		1.5	1½	1	0	0	0	1	0	0	0	0	0	3	0	0
		1.5	1	1	0	0	0	0	0	0	0	0	0	0	0	0
		2.5	¾	1	0	0	0	0	0	0	0	0	0	0	0	0
Aug. 15	......	2	1	2	0	0	0	0	0	0	0	0	0	0	0	0
		2	1	1	0	0	0	0	0	0	0	0	0	0	0	0
		2	1	1	0	0	0	0	0	0	0	0	0	0	0	0
		3.5	1	.7	0	0	0	0	0	0	0	0	0	0	0	0
		1.5	¾	1.7	0	0	0	0	0	.5	0	0	0	0	0	0
		1.5	¾	.9	.9	0	0	1	0	0	0	0	0	0	0	0
		3.5	¾	.7	0	0	0	0	0	0	0	0	0	0	0	0
		1.5	¾	1	3	0	0	0	0	0	0	0	0	0	0	0
Aug. 19	26.8	1	1	13	2.4	0	0	0	.8	0	0	0	0	0	0	0
Aug. 20	......	2.8	1½	3.2	0	0	0	0	0	.7	0	0	0	0	0	0
		2.8	1	3	0	0	0	0	0	0	0	0	0	0	0	0
		2.8	¾	2.7	.3	0	0	0	0	0	0	0	.3	0	0	0
Aug. 29	......	1	¾	5	5	0	0	0	0	0	0	0	0	0	0	0
		1.5	1	4.8	0	0	0	.6	0	0	0	0	0	0	0	0
		2	1½	4.8	0	0	0	0	0	0	0	0	0	0	0	0
Sept. 5	......	1	¾	4.9	7	0	0	0	0	0	2.3	0	0	.7	0	0
		2	1	4.3	.4	.4	0	0	0	.5	0	0	0	0	0	0
		3	1½	4.5	0	0	0	0.2	0	0	0	0	0	1	0	0
Sept. 14	19.9	2	¾	4.1	3.3	0	0	0	0	0	0	0	0	0	0	0
		2.5	1	4.1	0	0	0	0	0	0	0	0	0	0	0	0
		3	1½	4	0	0	0	0	0	0	0	0	0	0	0	0
Sept. 23	14.5	3	1½	1.6	0	0	0	0	0	0	0	0	0	0	0	0
		2	1	1.4	0	0	0	0	0	0	0	0	0	0	0	0
		1.1	¾	1.3	1.6	0	0	0	0	0	0	0	0	0	0	0
		1	¾	2.6	0	0	0	0	0	.4	0	0	0	0	0	0
		1.5	1	2.6	.8	0	0	0	0	0	0	0	0	0	0	0
		2	1½	2.6	0	0	0	0	0	0	0	0	0	.8	0	0
Sept. 30	13.5	1.5	¾	4.3	1.7	0	0	0	0	0	0	0	0	0	0	0
		2	1	4	.5	0	0	0	0	0	0	0	0	0	0	0
		2.5	1½	3.7	0	0	0	0	0	0	0	0	0	0	0	0
Oct. 7	14.8	.7	¾	4.8	1.7	0	0	0	0	.2	0	0	0	.2	0	0
		1.5	1	4.5	.4	0	0	0	0	0	0	0	0	0	0	0
		2.5	1½	4.3	0	0	0	0	0	0	0	0	0	0	0	0
Oct. 10	14.2	1	1	2	.5	0	0	0	0	0	0	0	0	0	0	0
		1	1	1.7	0	0	0	0	0	0	0	0	0	0	0	0
		2	1½	1.7	0	0	0	0	0	0	0	0	0	0	0	0
		1	1½	1.7	0	0	0	0	0	0	0	0	0	0	0	0
Oct. 11	13.7	1.7	1	3.2	1.3	0	0	0	0	0	0	0	0	0	0	0
		2.5	1½	3.1	0	0	0	0	0	0	0	0	0	0	0	0
Oct. 12	......	1.7	1	14.8	.07	0	0	0	0	0	0	0	0	0	0	0
		2.5	1½	14.7	0	0	0	.07	0	0	0	0	0	0	0	0

TABLE 4.—FISHES CAUGHT PER HOUR IN GILL NETS, LAKE WINGRA, 1916—Continued.

Date.	Temperature (degrees centigrade).	Gill nets.			Perca flavescens.	Esox lucius.	Lepomis incisor.	Pomoxis sparoides.	Lepisosteus osseus.	Micropterus dolomieu.	Micropterus salmoides.	Abramis crysoleucas.	Cyprinus carpio.	Eupomotis gibbosus.	Amia calva.	Ameiurus nebulosus.
		Depth set (meters).	Size mesh (inches).	Hours in water.												
Oct. 14	12.3	1.7	1	48	.02	0	0	0	0	0	0	.02	.02	0	0	0
		2.5	1½	48	0	0	0	.06	0	0	0	0	.04	.02	0	0
		2.5	1½	3	0	0	0	0	0	0	0	0	0	0	0	0
		.8	¾	3	2.1	0	0	0	0	0	0	0	0	0	0	0
Oct. 20	8.5	1.6	1	31.8	.1	0	0	0	0	0	0	0	0	0	0	0
		3	1½	31.5	0	0	0	0	0	0	0	0	0	0	0	0
		3.3	2	31.1	0	.03	0	0	0	0	0	0	0	0	0	0
Oct. 28	4.1	2	1	48	.3	0	0	0	0	0	0	0	0	0	0	0
		3	1	47.5	0	0	0	0	0	0	0	0	.02	0	0	0
		3	2	47.5	0	0	0	0	0	0	0	0	0	0	0	0
Oct. 31	6.5	2	1	71.7	.08	0	0	0	0	0	0	0	.01	0	0	0
		3	1	71.9	0	0	0	0	0	0	0	0	.02	0	0	0
		3	2	71.9	0	0	0	0	0	0	0	0	0	0	0	0
		1.4	¾	.6	3.3	0	0	0	0	0	0	0	0	0	0	0
Nov. 4	7	2	1	96	.03	0	0	0	0	0	0	0	0	0	0	0
		3	1	96	0	0	0	0	0	0	0	0	0	0	0	0
		3	2	95.9	0	.01	0	0	0	0	0	0	0	0	0	0
		1.5	1	2.7	.6	0	0	0	0	0	0	0	0	0	0	0
		2	1½	2.4	0	0	0	0	0	0	0	0	0	0	0	0
		3	2	2.5	0	0	0	0	0	0	0	0	0	0	0	0
		1	¾	2.5	2.4	0	0	0	0	0	0	0	0	0	0	0
Nov. 5	......	1.5	1	19	.2	0	0	0	0	0	0	0	0	0	0	0
		2	1½	19	0	0	0	0	0	0	0	0	0	0	0	0
		3	2	19	0	0	0	0	0	0	0	0	0	0	0	0
Nov. 7	7.2	3	1	49	.1	0	0	0	0	0	0	0	0	0	0	0
		3	1½	49	0	0	0	0	0	0	0	0	0	0	0	0
		3	2	49	0	0	0	0	0	0	0	0	0	0	0	0
Nov. 9	8	3	1	48	.3	0	0	0	0	0	0	0	0	0	0	0
		3	1½	48	0	0	0	0	0	0	0	0	0	0	0	0
		3	2	48	0	0	0	0	0	0	0	0	0	0	0	0
Nov. 11	6.7	3.5	1	47.5	.2	0	0	0	0	0	0	0	0	0	0	0
		3.5	1½	47.5	0	0	0	0	0	0	0	0	0	0	0	0
		3.5	2	47.5	0	.02	0	0	.02	0	0	0	0	0	0	0
		1	¾	2	.5	0	0	0	0	0	0	0	0	0	0	0
Dec. 7[a]	......	1.5	¾	20.4	0	0	0	0	0	0	0	0	0	0	0	0
Dec. 8	3.8	1.5	¾	26	.03	0	0	0	0	0	0	0	0	0	0	0
Dec. 9[a]	2.2	1.5	¾	21.3	0	0	0	0	0	0	0	0	0	0	0	0

[a] Lake Wingra froze over on Nov. 15, but opened up again; it did not freeze over for the winter until Dec. 10.

TABLE 5.—PERCH CAUGHT PER HOUR AND PER DAY IN GILL NETS, LAKE WINGRA, 1916.[a]

Date.	Temperature (degrees centigrade).	Gill nets.					Perch caught.		
		Depth set (meters).	Size mesh (inches).	Time set.	Time pulled.	Hours in water.	Total.	Average per hour.	Average per 24 hours.
Apr. 8	....	2	¾	7.00 a. m.	11.00 a. m.	4	55	13.7	329
		2	1	7.00 a. m.	11.00 a. m.	4	3	.7	18
		2	2	7.00 a. m.	11.00 a. m.	4	0	0	0
		2	1	11.45 a. m.	2.30 p. m.	2.2	33	15	360
		2	2	11.45 a. m.	2.30 p. m.	2.2	0	0	0
Apr. 14	....	2	¾ and 1	....	....	.5	8	16	384
Apr. 20	10.6	.7	¾	7.00 a. m.	8.25 a. m.	1.3	26	17.3	415
		1	1½	6.50 a. m.	11.00 a. m.	4.2	0	0	0
		.7	2	6.50 a. m.	11.00 a. m.	4.2	0	0	0
		1	1	6.50 a. m.	11.00 a. m.	4.2	4	.9	22
Apr. 22	....	3	1½	7.10 a. m.	7.20 a. m.	.2	0	0	0
		1.5	¾	7.10 a. m.	8.15 a. m.	1.1	16	15	360
		1	1½	7.15 a. m.	8.50 a. m.	1.6	0	0	0
		1	1	7.20 a. m.	12.00 m.	4.6	0	0	0
		1.5	1½	9.00 a. m.	12.00 m.	3	0	0	0
		1.5	¾	8.00 a. m.	11.30 a. m.	3.5	0	0	0
		1.5	1	8.00 a. m.	11.30 a. m.	3.5	3	.9	22
		1.5	1	8.00 a. m.	11.30 a. m.	3.5	0	0	0
Apr. 29	....	2	1	11.45 a. m.	1.00 p. m.	1.4	0	0	0
		2	1½	7.45 a. m.	8.10 a. m.	.5	0	0	0
		1	¾	6.35 a. m.	8.15 a. m.	1.6	9	5.6	134
		2	1	6.35 a. m.	8.50 a. m.	2.3	0	0	0
		2	1½	8.10 a. m.	10.15 a. m.	2.1	0	0	0
		2	¾	8.10 a. m.	10.15 a. m.	2.1	0	0	0
		1.5	1½	7.45 a. m.	8.00 a. m.	.4	0	0	0
		1.5	1	7.45 a. m.	8.00 a. m.	.4	0	0	0
		1	1½	10.30 a. m.	11.45 a. m.	1.2	0	0	0
		1	1	10.30 a. m.	11.45 a. m.	1.2	0	0	0
		1.5	1½	10.30 a. m.	11.45 a. m.	1.2	0	0	0
		1.2	1	10.30 a. m.	11.45 a. m.	1.2	0	0	0
May 6	....	1	¾	6.30 a. m.	9.35 a. m.	3.1	42	13.7	329
		1	1	6.30 a. m.	9.45 a. m.	3.2	0	0	0
		1	1½	6.30 a. m.	10.00 a. m.	3.5	0	0	0
		1	1	10.15 a. m.	11.00 a. m.	.7	4	5.2	125
		1	1½	10.15 a. m.	12.00 m.	1.7	0	0	0
		1.5	1½	11.30 a. m.	12.00 m.	.5	0	0	0
		1.5	1	12.00 m.	1.00 p. m.	1	0	0	0
		1.5	1	10.00 a. m.	11.00 a. m.	1	0	0	0
		1.5	1½	10.00 a. m.	11.00 a. m.	1	0	0	0
		1.5	1	1.00 p. m.	1.35 p. m.	.6	0	0	0
		1.5	1½	1.00 p. m.	1.35 p. m.	.6	0	0	0
May 13	16	2	1½	6.45 a. m.	9.00 a. m.	2.3	0	0	0
		2.5	1	7.00 a. m.	10.30 a. m.	3.5	0	0	0
		2	¾	7.00 a. m.	9.00 a. m.	2	13	6.5	156
		1	1	11.30 a. m.	12.45 p. m.	1.3	0	0	0
		1	1½	10.30 a. m.	11.30 a. m.	1	0	0	0
		1	1½	11.30 a. m.	1.00 p. m.	1.5	0	0	0
		1	1	12.45 a. m.	2.00 p. m.	1.3	9	7.1	170
		1	1½	12.45 p. m.	2.00 p. m.	1.3	0	0	0
May 20	....	1	1½	6.47 a. m.	8.30 a. m.	1.7	0	0	0
		1	1½	8.40 a. m.	9.12 a. m.	.5	0	0	0
		1.5	1½	9.12 a. m.	9.28 a. m.	.3	0	0	0
		1.5	1½	9.28 a. m.	10.50 a. m.	1.3	0	0	0
		1	1	6.53 a. m.	8.35 a. m.	1.6	0	0	0
		1	1	8.43 a. m.	10.40 a. m.	2	0	0	0
		1.5	¾	6.58 a. m.	7.58 a. m.	1	16	16	384
		1.5	¾	8.45 a. m.	9.18 a. m.	.5	5	10	240
		1.5	¾	9.35 a. m.	10.30 a. m.	1	13	13	312
May 27	26	1	1½	8.00 a. m.	9.30 a. m.	1.5	0	0	0
		1	1½	6.45 a. m.	8.00 a. m.	1.3	0	0	0
		1	1½	9.30 a. m.	11.00 a. m.	1.5	0	0	0
		1	1	7.00 a. m.	8.30 a. m.	1.5	0	0	0
		1	1	8.30 a. m.	10.30 a. m.	1.5	0	0	0
		1	1	10.00 a. m.	11.30 a. m.	1.5	2	1.3	31
		1	1	11.30 a. m.	2.00 p. m.	2.5	0	0	0
		1	¾	7.20 a. m.	9.00 a. m.	1.6	63	37.8	907
June 3	....	1	¾	6.53 a. m.	7.55 a. m.	1	21	21	504
		1	¾	7.55 a. m.	9.10 a. m.	1.2	11	8.8	211
		1	¾	9.10 a. m.	9.30 a. m.	.3	4	12	288
		1	¾	9.30 a. m.	9.52 a. m.	.3	3	9	216
		1	1	7.00 a. m.	8.05 a. m.	1.1	0	0	0
		1	1	9.15 a. m.	9.45 a. m.	.5	0	0	0
		1	1	8.15 a. m.	9.15 a. m.	1	0	0	0
		1	1½	7.25 a. m.	8.10 a. m.	.7	0	0	0
		1	1½	8.10 a. m.	9.25 a. m.	1.3	0	0	0
		1	1½	10.30 a. m.	11.30 a. m.	1	0	0	0
		1	¾	10.35 a. m.	11.25 a. m.	.8	1	1.2	29
		1	1	10.40 a. m.	11.20 a. m.	.6	0	0	0

[a] In all nets the mesh sizes were bar measure. The 1-inch mesh nets were 60 feet long; all others, 75 feet long.

TABLE 5.—PERCH CAUGHT PER HOUR AND PER DAY IN GILL NETS, LAKE WINGRA, 1916—Contd.

Date.	Temperature (degrees centigrade).	Gill nets.					Perch caught.		
		Depth set (meters).	Size mesh (inches).	Time set.	Time pulled.	Hours in water.	Total.	Average per hour.	Average per 24 hours.
June 10	20.5	2	1½	6.43 a. m.	8.42 a. m.	2.2	0	0	0
		1	1	6.57 a. m.	7.58 a. m.	1	0	0	0
		1.5	¾	7.05 a. m.	7.48 a. m.	.7	6	8	192
		1.5	¾	7.48 a. m.	8.15 a. m.	.5	4	8	192
June 17	....	1	¾	5.50 a. m.	7.03 a. m.	1.3	11	8.8	211
		1	¾	7.03 a. m.	9.00 a. m.	2	21	10.5	252
		1.5	1	6.10 a. m.	7.20 a. m.	1.1	0	0	0
		1.5	1	7.20 a. m.	9.30 a. m.	2.1	0	0	0
		1.5	1½	6.32 a. m.	7.32 a. m.	1	0	0	0
		1.5	1½	7.32 a. m.	9.45 a. m.	2.3	0	0	0
		1.5	1	10.00 a. m.	11.30 a. m.	1.5	0	0	0
		1.5	1	10.00 a. m.	11.30 a. m.	1.5	0	0	0
		1.5	1	11.30 a. m.	1.00 p. m.	1.5	0	0	0
		1.5	1	1.00 p. m.	1.45 p. m.	.7	0	0	0
		1.5	1½	9.45 a. m.	10.15 a. m.	.5	0	0	0
		1.5	1½	10.15 a. m.	12.00 m.	1.7	0	0	0
		1.5	1½	10.30 a. m.	12.00 m.	1.5	0	0	0
July 22	30	1.8	1½	6.58 a. m.	9.03 a. m.	2.1	0	0	0
		2.4	1	6.50 a. m.	9.00 a. m.	2.2	2	.7	16
		3.1	¾	6.40 a. m.	8.45 a. m.	2	78	39	936
July 26	29.4	2.4	¾	7.12 a. m.	9.03 a. m.	1.8	15	8.2	196
		3.1	1	6.50 a. m.	9.03 a. m.	2.1	0	0	0
		3.7	1½	6.40 a. m.	8.59 a. m.	2.3	0	0	0
		3.1	¾	9.20 a. m.	11.00 a. m.	1.6	2	1.2	29
		2.4	1	9.20 a. m.	11.00 a. m.	1.6	2	1.2	29
		2.2	1½	9.20 a. m.	11.00 a. m.	1.6	0	0	0
Aug. 5	....	2.7	¾	6.40 a. m.	9.30 a. m.	2.8	8	2.9	70
		2.7	1	6.40 a. m.	9.30 a. m.	2.8	0	0	0
		2.7	1½	6.40 a. m.	9.30 a. m.	2.8	0	0	0
Aug. 11	26	2.9	¾	9.00 a. m.	10.30 a. m.	1.5	0	0	0
		2.9	1	9.04 a. m.	10.30 a. m.	1.4	0	0	0
		3	1½	9.10 a. m.	10.30 a. m.	1.3	0	0	0
		3.5	¾	10.50 a. m.	12.25 p. m.	1.7	0	0	0
		3.3	1	10.53 a. m.	12.25 p. m.	1.7	0	0	0
		3.1	1½	10.55 a. m.	12.25 p. m.	1.5	0	0	0
		1.5	1½	1.31 p. m.	2.30 p. m.	1	0	0	0
		1.5	1	1.35 p. m.	2.35 p. m.	1	0	0	0
		2.5	¾	1.42 p. m.	2.40 p. m.	1	0	0	0
Aug. 15	....	2	1	8.45 a. m.	10.45 a. m.	2	0	0	0
		2	1	11.00 a. m.	12.00 m.	1	0	0	0
		3.5	1	12.30 p. m.	1.15 p. m.	.7	0	0	0
		2	1	1.40 p. m.	2.40 p. m.	1	0	0	0
		1.5	¾	9.05 a. m.	10.50 a. m.	1.7	0	0	0
		1.5	¾	11.05 a. m.	12.00 m.	.9	1	.9	22
		3.5	¾	12.35 p. m.	1.20 p. m.	.7	0	0	0
		1.5	¾	1.40 p. m.	2.40 p. m.	1	3	3	72
Aug. 19	26.8	1	1	7.35 a. m.	8.40 a. m.	13	32	2.4	26
Aug. 20	....	2.8	1½	5.10 a. m.	8.20 a. m.	3.2	0	0	0
		2.8	1	5.22 a. m.	8.18 a. m.	3	0	0	0
		2.8	¾	5.35 a. m.	8.12 a. m.	2.7	1	.3	7
Aug. 29	....	1	¾	6.05 a. m.	11.00 a. m.	5	25	5	120
		1.5	1	6.10 a. m.	11.03 a. m.	4.8	0	0	0
		2	1½	6.15 a. m.	11.05 a. m.	4.8	0	0	0
Sept. 5	....	1	¾	6.15 a. m.	11.10 a. m.	4.9	35	7	168
		2	1	6.22 a. m.	11.00 a. m.	4.3	2	.4	10
		3	1½	6.28 a. m.	10.55 a. m.	4.5	0	0	0
Sept. 14	19.9	2	¾	6.15 a. m.	10.20 a. m.	4.1	13	3.3	79
		2.5	1	6.20 a. m.	10.25 a. m.	4.1	0	0	0
		3	1½	6.26 a. m.	10.28 a. m.	4	0	0	0
Sept. 23	14.5	3	1½	6.15 a. m.	7.50 a. m.	1.6	0	0	0
		2	1	6.24 a. m.	7.50 a. m.	1.4	0	0	0
		1.1	¾	6.32 a. m.	7.50 a. m.	1.3	2	1.6	38
		1	¾	8.10 a. m.	10.45 a. m.	2.6	0	0	0
		1.5	1	8.14 a. m.	10.50 a. m.	2.6	2	.8	19
		2	1½	8.18 a. m.	10.55 a. m.	2.6	0	0	0
Sept. 30	13.5	1.5	¾	6.30 a. m.	10.45 a. m.	4.3	7	1.7	31
		2	1	6.45 a. m.	10.42 a. m.	4	2	.5	12
		2.5	1½	6.55 a. m.	10.38 a. m.	3.7	0	0	0
Oct. 7	14.8	.7	¾	6.23 a. m.	11.08 a. m.	4.8	8	1.7	31
		1.5	1	6.32 a. m.	11.04 a. m.	4.5	2	.4	10
		2.5	1½	6.43 a. m.	11.00 a. m.	4.3	0	0	0
Oct. 10	14.2	1	1	2.00 p. m.	3.57 p. m.	2	1	.5	12
		1	1	4.07 p. m.	5.50 p. m.	1.7	0	0	0
		2	1½	2.10 p. m.	3.55 p. m.	1.7	0	0	0
		2	1½	4.09 p. m.	5.50 p. m.	1.7	0	0	0
Oct. 11	13.7	1.7	1	1.55 p. m.	5.09 p. m.	3.2	4	1.3	31
		2.5	1½	2.00 p. m.	5.06 p. m.	3.1	0	0	2
Oct. 12	....	1.7	1	5.09 p. m.	7.55 a. m.	14.8	1	.07	0
		2.5	1½	5.06 p. m.	7.50 a. m.	14.7	0	0	0

TABLE 5.—PERCH CAUGHT PER HOUR AND PER DAY IN GILL NETS, LAKE WINGRA, 1916—Contd.

Date.	Temperature (degrees centigrade).	Gill nets.					Perch caught.		
		Depth set (meters).	Size mesh (inches).	Time set.	Time pulled.	Hours in water.	Total.	Average per hour.	Average per 24 hours.
Oct. 14	12.3	1.7	1	7.55 a. m.	7.50 a. m.	48	1	.02	.5
		2.5	1½	7.50 a. m.	10.50 a. m.	3	0	0	0
		2.5	1½	7.50 a. m.	7.45 a. m.	48	0	0	0
		.8	¾	7.45 a. m.	10.45 a. m.	3	6	2.1	50
Oct. 20	8.5	1.6	1	8.10 a. m.	4.00 p. m.	31.8	3	.1	2
		3	1½	8.20 a. m.	3.50 p. m.	31.5	0	0	0
		3.3	2	8.30 a. m.	3.40 p. m.	31.1	0	0	0
Oct. 28	4.1	2	1	8.25 a. m.	8.30 a. m.	48	13	.3	7
		3	1	8.35 a. m.	8.10 a. m.	47.5	0	0	0
		3	2	8.43 a. m.	8.15 a. m.	47.5	0	0	0
Oct. 31	6.5	2	1	8.30 a. m.	8.15 a. m.	71.7	6	.08	2
		3	1	8.10 a. m.	8.03 a. m.	71.9	0	0	0
		3	2	8.15 a. m.	8.08 a. m.	71.9	0	0	0
		1.4	¾	8.05 a. m.	8.43 a. m.	.6	2	3.3	79.2
Nov. 4	7	2	1	8.15 a. m.	8.12 a. m.	96	3	.03	.7
		3	1	8.03 a. m.	8.05 a. m.	96	0	0	0
		3	2	8.08 a. m.	8.00 a. m.	95.9	0	0	0
		1.5	1	8.30 a. m.	11.10 a. m.	2.7	2	.6	14
		2	1½	8.32 a. m.	11.08 a. m.	2.4	0	0	0
		3	2	8.35 a. m.	11.08 a. m.	2.5	0	0	0
		1	¾	8.57 a. m.	11.20 a. m.	2.5	6	2.4	57
Nov. 5		1.5	1	11.10 a. m.	6.05 a. m.	19	4	.2	5
		2	1½	11.08 a. m.	6.05 a. m.	19	0	0	0
		3	2	11.08 a. m.	6.05 a. m.	19	0	0	0
Nov. 7	7.2	3	1	6.35 a. m.	7.40 a. m.	49	7	.1	3
		3	1½	6.35 a. m.	7.40 a. m.	49	0	0	0
		3	2	6.35 a. m.	7.40 a. m.	49	0	0	0
Nov. 9	8	3	1	8.10 a. m.	8.00 a. m.	48	16	.3	8
		3	1½	8.10 a. m.	8.00 a. m.	48	0	0	0
		3	2	8.10 a. m.	8.00 a. m.	48	0	0	0
Nov. 11	6.7	3.5	1	8.40 a. m.	8.05 a. m.	47.5	10	.2	5
		3.5	1½	8.40 a. m.	8.05 a. m.	47.5	0	0	0
		3.5	2	8.40 a. m.	8.05 a. m.	47.5	0	0	0
		1	¾	8.40 a. m.	10.40 a. m.	2	24	.5	12
Dec. 7[a]		1.5	¾	12.00 m.	8.25 a. m.	20.4	0	0	0
Dec. 8	3.8	1.5	¾	8.52 a. m.	10.47 a. m.	26	1	.03	.7
Dec. 9[a]	2.2	1.5	¾	10.50 a. m.	8.06 a. m.	21.3	0	0	0

[a] Lake Wingra froze over on Nov. 15, but opened up again; it did not freeze over for the winter until Dec. 10.

TABLE 6.—FOOD OF 499 ADULT PERCH IN LAKE MENDOTA, 1915, SHOWN BY MONTHS.

[All figures referring to food indicate percentage by volume; + means a trace.]

Month.	Perch.		Fish.	Chironomid larvæ.	Corethra larvæ.	Probezzia larvæ.	Ephemerid nymphs.	Caddisfly larvæ.	Odonate nymphs.	Sialis larvæ.	Unidentified larvæ.	Chironomid pupæ.	Corethra pupæ.	Chironomid adults.	Corethra adults.	Winged ants.	Sialis adults.
	Number examined.	Average length (millimeters)															
January	40	166.6	......	3.3	7.5	......	0.5	0.2	......	0.6	0.1	......	......	......	......	......	......
February	37	166.2	......	5.2	15.5	......	......	......	......	1.0	......	......	......	......	......	......	......
March	39	165.1	0.2	10.2	11.1	......	......	......	1.0	11.5	......	......	......	......	......	......	......
April	26	170.7	10.2	9.0	.3	......	......	1.3	......	16.0	......	2.1	......	1.5	......	......	......
May	56	171.0	3.8	35.6	3.1	0.4	1.1	1.3	......	.7	......	3.4	......	1.5	......	......	......
June	49	161.2	......	24.6	8.3	.8	.7	13.3	.2	1.5	.2	20.3	0.3	.7	......	......	0.7
July	64	164.7	1.5	26.0	9.2	......	.1	.3	......	.3	.4	16.7	1.0	......	......	......	......
August	41	163.0	......	18.0	1.6	.1	......	1.2	......	4.4	......	2.4	.3	......	6.0	......	......
September	39	165.8	3.3	11.7	10.6	......	......	.4	......	3.4	......	6.5	......	......	.3	0.6	......
October	50	164.8	......	2.8	3.6	......	.1	.6	......	1.5	......	15.7	......	......	......	......	......
November	37	172.3	2.6	5.6	2.2	......	......	+	......	2.1	......	.1	......	......	......	......	......
December	21	165.4	.5	7.2	2.6	......	......	......	......	5.0	......	......	......	......	......	......	......
Average	......	166.3	1.8	13.3	6.3	.1	.2	1.6	.1	4.0	.1	5.6	.1	.3	.5	.1	.1

Month.	Corixa adults.	Unidentified adult insects.	Mites.	Amphipods.	Crayfishes.	Ostracods.	Copepods.	Cladocera.	Gastropods.	Lamellibranchs.	Leeches.	Oligochætes.	Filamentous algæ.	Algæ.	Plants.	Fine débris.	Sand and stones.
January	......	......	......	1.0	......	......	0.6	56.3	......	1.5	......	0.8	1.0	......	13.7	10.2	......
February	......	......	......	......	......	......	......	45.2	......	3.6	......	......	.1	0.2	12.9	14.6	......
March	......	......	......	......	......	......	......	18.6	......	3.5	......	......	......	......	18.7	21.7	......
April	......	......	3.8	8.8	......	......	.1	14.0	3.6	.3	3.7	......	......	1.5	10.6	10.8	......
May	0.4	+	4.0	8.3	2.4	......	......	16.1	7.1	.1	1.4	......	.4	......	2.6	2.5	......
June	......	0.2	.2	4.8	......	......	1.5	16.3	.6	.4	.5	......	......	......	1.7	1.0	......
July	......	......	......	2.9	7.4	......	......	24.4	......	3.9	......	......	......	5.8	.6	......	0.1
August	......	......	......	.6	3.6	0.1	.3	49.0	2.5	.2	......	5.3	.1	.3	2.4	......	.2
September	......	......	......	2.5	6.8	.1	.1	30.6	6.5	1.0	......	7.4	.6	......	6.7	1.1	.2
October	......	......	......	1.8	.6	......	.1	60.2	1.4	1.4	.4	1.7	.1	.4	3.1	4.0	......
November	2.3	......	......	3.9	......	.1	......	45.6	1.1	4.4	......	5.1	.1	......	9.7	12.7	......
December	......	......	......	1.1	......	.3	.4	54.7	1.0	......	......	3.3	1.0	......	6.6	15.5	......
Average	.2	+	.7	3.0	1.7	.1	.3	36.0	2.0	1.7	.5	2.0	.3	.7	7.4	7.8	+

TABLE 7.—FOOD OF 188 ADULT PERCH IN LAKE MENDOTA, 1916, SHOWN BY MONTHS.

[All figures referring to food indicate percentage by volume; + means a trace.]

Month.	Perch.		Fish eggs.	Fish.	Chironomid larvæ.	Corethra larvæ.	Ephemerid nymphs.	Caddisfly larvæ.	Odonate nymphs.	Sialis larvæ.	Chironomid pupæ.	Corethra pupæ.	Coleoptera adults.
	Number examined.	Average length (millimeters).											
January	10	172.8	....	....	10.8	10.4	....	....	....	16.5	....	....	....
February	10	166.0	....	....	1.8	25.8	....	....	....	....	....	....	....
March	10	159.4	....	....	12.5	31.9	....	....	....	2.0	....	....	....
April	39	167.2	....	....	7.3	15.4	....	....	....	....	....	....	....
May	32	170.7	9.6	....	25.5	5.9	....	1.4	1.1	5.5	....	....	....
June	16	163.8	....	....	17.3	4.1	+	3.7	.5	....	7.8	1.8	....
July	33	167.1	....	6.0	27.2	16.2	....	2.6	....	....	16.5	4.1	0.1
August	14	157.1	....	....	32.0	7.7	....	21.0	....	....	1.2	.3	....
September	10	167.1	....	....	21.8	46.0	....	....	....	....	.1	....	....
December	14	169.0	....	....	8.1	7.0	....	....	....	7.8	....	....	....
Average	......	166.0	1.0	0.6	16.4	17.0	+	2.9	.2	3.2	2.6	.6	+

Month.	Unidentified adults.	Crayfishes.	Amphipods.	Ostracods.	Copepods.	Cladocera.	Gastropods.	Lamellibranchs.	Leeches.	Oligochætes.	Algæ.	Plants.	Silt and débris.	CaCO₃ crystals.
January	....	....	....	2.5	3.6	35.1	....	....	....	1.0	1.7	4.0	14.4	....
February	....	....	....	9.3	.2	7.0	0.2	1.5	....	7.5	2.0	19.6	24.5	0.5
March	....	....	12.2	1.6	.5	....	....	....	....	1.0	2.0	7.0	21.2	8.1
April	....	....	.7	.1	....	....	....	....	....	6.9	1.7	18.7	36.8	9.3
May	....	....	3.1	....	.2	3.0	3.2	7.2	3.7	12.0	.3	.2	20.0	....
June	0.3	6.2	21.3	....	+	22.2	+	11.5	.1	+	....	+	3.2	....
July	.9	8.2	1.7	....	....	10.0	2.8	1.1	+	....	.5	+	1.0	....
August	....	6.7	12.6	....	.1	16.7	....	....	....	....	.2	.3	.3	....
September	....	3.5	....	....	.1	26.3	....	.4	....	+	....	.2	1.1	....
December	....	....	....	2.1	.2	65.7	....	....	....	....	....	2.1	6.3	....
Average	.1	2.5	5.2	1.6	.5	18.6	.6	2.2	.4	2.8	.8	5.2	12.9	1.8

TABLE 8.—FOOD OF 350 ADULT PERCH IN LAKE WINGRA, 1916–17, SHOWN BY MONTHS.

[All figures referring to food indicate percentage by volume; + means a trace.]

Month.	Perch.		Fish.	Chironomid larvæ.	Corethra larvæ.	Ephemerid nymphs.	Caddisfly larvæ.	Odonate nymphs.	Hemiptera nymphs.	Sialis larvæ.	Chironomid pupæ.	Chironomid adults.	Coleoptera adults.	Hemiptera adults.
	Number examined.	Average length (millimeters).												
March	16	131.7	8.7	48.2	0.3	0.9	....	7.2	....	....	5.0	....	....	0.1
April	47	134.8	4.5	45.5	....	17.9	....	3.7	....	....	3.5	2.7	1.0	.3
May	40	129.4	....	24.6	....	4.2	6.0	13.9	....	....	21.7	....	....	4.7
June	40	130.3	1.0	46.8	....	1.9	.7	.2	4.4	....	30.4	....	....	.5
July	47	138.8	10.3	62.6	.1	....	.3	.2	....	....	22.9	....	....	....
August	21	133.3	41.9	14.4	.5	....	....	....	....	....	25.3	....	....	....
September	39	144.5	7.4	10.1	.7	....	1.0	....	....	3.6	15.6	....	....	....
October	31	155.6	17.7	41.2	1.1	.2	2.4	7.0	....	....	.9	....	....	.6
November	26	155.7	16.0	48.2	....	.9	3.5	3.2	....	2.3	....	....	....	3.5
December	2	141	....	64.0	....	....	....	....	....	32.5	....	....	....	....
January	16	149.2	41.5	25.8	1.2	3.0	....	16.6	....	....	....	....	....	....
February	25	154.4	35.3	21.3	....	5.2	....	7.8	....	....	....	....	....	4.0
Average	......	141.6	15.4	37.7	.3	2.9	1.2	5.0	.4	3.2	10.4	.2	.1	1.1

Month.	Unidentified adult insects.	Mites.	Amphipods.	Isopods.	Ostracods.	Copepods.	Cladocera.	Gastropods.	Lamellibranchs.	Leeches.	Oligochætes.	Algæ.	Plants.	Silt and débris.
March	....	....	5.8	....	....	0.8	13.1	....	....	1.2	1.2	1.8	0.6	....
April	....	....	7.4	....	....	1.3	.6	1.7	....	.7	....	3.9	.3	3.2
May	....	0.1	3.6	....	....	....	13.8	.1	....	....	....	.7	.1	2.0
June	....	1.8	.2	....	0.6	....	3.9	.8	0.5	.1	....	2.5	.3	.4
July	....	....	.2	....	+	+	+	....	....	.3	+	.[illegible]	.5	.5
August	....	....	....	....	....	....	2.0	....	....	....	....	4.7	2.8	3.4
September	....	.2	.2	....	....	.1	54.7	....	....	....	....	1.0	2.9	.5
October	1.3	....	3.2	....	+	....	16.1	.1	.1	....	....	3.4	2.3	1.1
November	....	....	1.7	....	.1	+	17.5	.5	....	....	....	1.7	....	1.8
December	....	....	....	....	....	....	1.5	....	....	2.0	....	....	....	....
January	....	....	1.0	....	....	....	5.4	....	....	.6	....	2.0	1.0	.6
February	....	.2	8.9	4.2	1.9	2.1	.4	....	....	....	1.7	1.2	.8	....
Average	.1	.2	2.7	.3	.2	.4	10.8	.3	.1	.4	.2	1.9	.9	1.1

TABLE 9.—MEAN OF FOODS EATEN BY PERCH IN LAKE WINGRA, 1916–17, AND IN LAKE MENDOTA, 1915–16.

[Boldface indicates maximum for month and for average; italics, the next largest amount. Figures indicate percentage of food by volume; + means a trace.]

Food.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Average.
Fish and fish eggs	*13.8*	11.8	3.0	4.9	4.5	0.3	5.9	14.0	3.6	8.9	9.3	0.2	6.8
Chironomid larvæ	13.3	9.4	**23.6**	**20.6**	**28.6**	**29.6**	**38.6**	*21.5*	14.5	*22.0*	*26.9*	*26.4*	**22.9**
Corethra larvæ	6.4	*13.8*	*14.4*	5.2	3.0	4.1	8.5	3.3	*19.1*	2.4	1.1	3.2	7.0
Ephemerid nymphs	1.2	1.7	.3	6.0	1.8	.9	0.0	0.0	0.0	.1	.3	0.0	1.0
Caddisfly larvæ	.1	0.0	0.0	.4	2.9	5.9	1.1	7.4	.5	1.5	1.8	0.0	1.8
Odonate nymphs	5.5	2.6	2.7	1.2	5.0	.3	.1	0.0	0.0	3.5	1.6	0.0	1.9
Sialis larvæ	5.7	.3	4.5	5.3	2.1	.5	.1	1.5	2.3	.8	2.2	15.1	3 4
Chironomid pupæ	0.0	0.0	1.7	2.9	8.4	*19.5*	*18.7*	9.6	7.4	8.3	+	0.0	6.4
Corethra pupæ	0.0	0.0	0.0	0.0	0.0	.7	1.7	.2	0.0	0.0	0.0	0.0	.2
Corethra adults	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	.1	0.0	0.0	0.0	.2
Chironomid adults	0.0	0.0	0.0	1.4	.5	.2	0.0	0.0	0.0	0.0	0.0	0.0	.2
Hemiptera adults	0.0	1.3	0.0	.1	1.7	.2	0.0	0.0	0.0	.3	2.9	0.0	.5
Other insects	0.0	0.0	0.0	.5	.1	.1	.3	0.0	.2	.4	0.0	0.0	.1
Mites	0.0	0.0	0.0	1.3	1.4	.7	0.0	0.0	.1	0.0	0.0	0.0	.3
Amphipods	.7	3.0	6.0	5.6	5.0	8.8	1.6	4.4	.9	2.5	2.8	.4	3.5
Isopods	0.0	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.1
Crayfishes	0.0	0.0	0.0	0.0	.8	2.1	5.2	3.4	3.4	.3	0.0	0.0	1.3
Ostracods	.8	3.7	.5	+	0.0	.2	+	+	+	+	.1	.8	.5
Copepods	1.4	.8	.4	.5	.1	.5	+	.1	.1	+	+	.2	.3
Cladocera	**32.3**	**17.6**	10.6	4.9	*11.0*	14.1	11.5	**22.6**	**37.2**	**38.2**	**31.6**	**40.6**	*22.7*
Gastropods	0.0	.1	0.0	1.8	3.5	.5	.9	.8	2.2	.8	.8	.3	1.0
Lamellibranchs	.5	1.7	1.2	.1	2.4	4.1	1.7	.1	.5	.8	2.2	0.0	1.3
Leeches	.2	0.0	.4	1.5	1.7	.2	.1	0.0	0.0	.1	0.0	.7	.4
Oligochætes	.6	3.1	.7	2.3	4.0	+	+	1.8	2.5	.9	2.6	1.1	1.6
Algæ	1.2	1.1	1.3	2.4	.3	.8	2.1	1.7	.3	1.9	.9	0.0	1.2
Plants	6.2	11.1	8.8	9.9	1.0	.7	.4	1.8	3.3	2.7	4.9	2.9	4.5
Silt and débris	8.4	13.0	14.3	*16.9*	8.2	1.5	.5	1.3	1.0	2.6	7.3	7.3	6.9
$CaCO_3$ crystals	0.0	.2	2.7	3.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.5

TABLE 10.—LARGEST NUMBER OF VARIOUS SPECIES OF ANIMALS FOUND IN A SINGLE PERCH AS A CONSTITUENT OF THE FOOD, 1915–16.

Date.	Locality.	Size of perch (millimeters)	Chief food constituent.			Other food constituents expressed in per cent of total food.
			Kind.	Number eaten.	Per cent of total food.	
Apr. 22, 1915	Lake Wingra	178	Minnows	4	90.0	Fish remains, 10.
May 8, 1916	East of Picnic Point, Lake Mendota.	164	Chironomus fulviventris larvæ.	105	30.0	Mites, 24; crayfish, 35; plant remains, 5; débris, 5; mayfly nymph, 1.
May 27, 1916	Lake Wingra	133	Damselfly nymphs	45	92.5	Filamentous algæ, 5; plant remains, 2; mayfly nymphs, 5.
Mar. 20, 1915	North of University of Wisconsin, Lake Mendota.	144	Procladius larvæ	77	45.0	Aphanothece, 10; Corethra larvæ, 20; fine silt and débris, 5; plant remains, 20.
June 5, 1915	do	172	Corethra larvæ	150	100.0	
Do	do	162	Leptocella uwarowii larvæ.	40	95.0	Chironomid cases and larvæ, 5.
June 12, 1915	do	170	Chironomid pupæ	300	97.0	Chironomid cases, 3.
Sept. 4, 1915	do	178	Camponotus adults	1,000	25.0	Insect remains, 5; Chironomus decorus pupæ, 5; Leptodora, 30; Daphnia hyalina, 35.
May 8, 1915	East of Picnic Point, Lake Mendota.	164	Mites	89	24.0	Chironomus fulviventris larvæ, 30; crayfish, 35; plant remains, 5; débris, 5; mayfly nymph, 1.
June 13, 1916	North of University of Wisconsin, Lake Mendota.	153	Hyalella	610	80.0	Chironomid larvæ, 2; chironomid pupæ, 8; caddisfly larvæ, 10.
Feb. 1, 1916	Northeast of Picnic Point, Lake Mendota.	156	Ostracods	595	93.5	Corethra larvæ, 3; Chironomus decorus larvæ, 2; Rivularia, 0.5; plant remains, 1.
Aug. 28, 1915	North of University of Wisconsin, Lake Mendota.	162	Leptodora	800	95.0	Daphnia hyalina, 2; Corethra adults, 3.
July 24, 1915	do	168	Daphnia hyalina	3,644	100.0	
Nov. 27, 1915	do	172	Amnicola limosa	32	27.0	Hyalella, 64.5; Leptodora, 27; caddisfly larvæ, 1; chironomid larvæ, 0.3; filamentous algæ, 0.2.
Aug. 28, 1915	do	160	Physa heterostropha	195	99.9	Spartina, 0.1
July 3, 1915	do	173	Sphæridæ	119	50.0	Daphnia hyalina, 10; chironomid larvæ, 10; chironomid pupæ, 30; Amnicola, 1.
Jan. 17, 1915	do	186	Oligochætes	20	30.0	Sialis infumata larvæ, 0.5; fine débris, 15; plant remains, 50.

TABLE 11.—RATE OF DIGESTION OF VARIOUS FOODS AT A NEARLY UNIFORM TEMPERATURE, 16.6° C.[a]

Temperature (degrees centigrade).	Food eaten.	Time in hours until first feces.		
		Shortest.	Longest.	Average.
16.5	Chironomid larvæ	5.0	7.0	6.0
16.3	Entomostraca	4.5	6.8	5.4
16.8	Earthworms	7.16	23.0	19.2
16.8	Hyalella	5.5	24.0	8.4
16.5	Liver and flour	3.25	23.0	[b] 15.8
17.0	Fish	24.0	24.0	[c] 24.0

[a] 10 perch were used; minimum weight, 1.9 g.; maximum weight, 4.67 g.; average weight, 2.85 g. When possible, as with chironomid larvæ and earthworms, the rate of digestion was computed from the time the fish began to eat; in a few cases (Entomostraca), from the time the food was placed in the dish. The experiments extended from Sept. 16 to Oct. 2, 1916.

[b] Not eaten by 5 individuals.

[c] Not eaten by 3 individuals.

TABLE 12.—RATE OF DIGESTION OF VARIOUS FOODS AT TEMPERATURES OF ABOUT 3 AND 18° C.[a]

Date.	Temperature (degrees centigrade).	Food eaten.		Average rate of digestion (hours).
		Kind.	Number.	
Jan. 24, 1917	2.5	Chironomid larvæ	3	43.7
Do	18.0	.....do	16	22.0
Jan. 17, 1917	2.5	Corethra larvæ	(?)	47.5
Jan. 15, 1917	18.0	.....do	(?)	23.0
Dec. 18, 1916	3.5	Dikerogammarus	3	64.0
Jan. 8, 1917	2.5	Earthworms	1	39.0
Do	17.0	.....do	1	18.4
Jan. 22, 1917	2.5	Liver and flour	0	....
Jan. 1, 1917	2.5	Minnows	1	43.3
Do	20.5	.....do	1	16.4
Dec. 26, 1916	4.5	Snails	0	....

[a] 2 experiments were conducted simultaneously, using 2 perch in each case, averaging 28 g. in weight. When possible, as with chironomid larvæ and earthworms, the rate of digestion was computed from the time the fish began to eat; in a few cases (Corethra larvæ), from the time the food was placed in the dish.

TABLE 13.—RATE OF DIGESTION OF VARIOUS FOODS AT TEMPERATURES VARYING FROM 23 TO 26° C.[a]

Date.	Temperature (degrees centigrade).	Food eaten.					Average rate of digestion (hours).
		Kind.	Number.		Volume (c. c.).		
			Total.	Per hour.	Total.	Per hour.	
June 19, 1916	23	Damselfly nymphs	24	1.5	2.5	0.15	31.7
July 20, 1916	26	Earthworms	5	.2	2.0	.16	20.0
July 5, 1916	23	Minnows	13	.57	5.2	.23	22.5

[a] In this experiment 1 perch weighing 48 g. was used.

TABLE 14.—RATE OF DIGESTION OF VARIOUS FOODS AT TEMPERATURES VARYING FROM 2.5 TO 4.5° C.[a]

Date.	Temperature (degrees centigrade).	Food eaten.		Average rate of digestion (hours).
		Kind.	Number.	
Jan. 24, 1917	2.5	Chironomid larvæ	50	46.5
Jan. 15, 1917	2.5	Corethra larvæ	(?)	48.0
Dec. 18, 1916	3.0	Dikerogammarus	13	64.0
Jan. 8, 1917	2.5	Earthworms	0	....
Jan. 22, 1917	2.5	Liver and flour	0	....
Jan. 1, 1917	2.5	Minnows	6	67.3
Dec. 26, 1916	4.5	Snails	0	....

[a] In this experiment 2 perch, weighing respectively 31 and 24 g., were used.

TABLE 15.—RATE OF DIGESTION AT DIFFERENT SEASONS, AS JUDGED BY INTERVAL BETWEEN EATING AND FIRST APPEARANCE OF FECES.

[Summary of data presented in Tables 11 to 14.]

Date.	Temperature (degrees centigrade).	Fish used.		Food eaten.		Average rate of digestion (hours).
		Number.	Average weight (grams).	Kind.	Number.	
Oct. 2, 1916	16.5	10	2.8	Chironomid larvæ	6	6.0
Jan. 24, 1917	2.5	2	2.8	.....do	3	43.7
Do	18.0	2	2.8	.....do	16	22.0
Do	2.5	2	27.5	.....do	50	46.5
Jan. 17, 1917	2.5	2	2.8	Corethra larvæ	(?)	47.5
Jan. 15, 1917	18.0	2	2.8	.....do	(?)	23.0
Do	2.5	2	27.5	.....do	(?)	48.0
June 19, 1916	23.0	1	48.0	Damselfly nymphs	24	31.7
Dec. 18, 1916	3.0	2	2.8	Dikerogammarus	3	64.0
Do	3.0	2	27.5	.....do	13	64.0
Sept. 29, 1916	16.3	10	2.8	Entomostraca	(?)	5.4
Sept. 20, 1916	16.8	10	2.8	Earthworms	1	19.2
Jan. 8, 1917	2.5	2	2.8	.....do	1	39.0
Do	17.0	2	2.8	.....do	1	18.4
July 20, 1916	26.0	1	48.0	.....do	5	20.0
Jan. 8, 1917	2.5	2	27.5	.....do	0	....
Sept. 25, 1916	16.8	10	2.8	Hyalella	(?)	8.4
Sept. 22, 1916	16.5	10	2.8	Liver and flour	(?)	15.8
Jan. 22, 1917	2.5	2	2.8	.....do	0	....
Do	2.5	2	27.5	.....do	0	....
Sept. 27, 1916	17.0	10	2.8	Minnows	1	24.0
Jan. 1, 1917	2.5	2	2.8	.....do	1	43.3
Jan. 5, 1917	20.5	2	2.8	.....do	1	15.4
July 5, 1916	23.0	1	48.0	.....do	13	22.5
Jan. 1, 1917	2.5	2	27.5	.....do	6	67.3
Dec. 26, 1916	4.5	2	2.8	Snails	0	....
June 30, 1916	24.0	1	48.0	.....do	0	....
Dec. 26, 1916	4.5	2	27.5	.....do	0	....
Oct. 10, 1916	17.0	10	2.8	Fish	....	24.0

TABLE 16.—PERCENTAGE OF VARIOUS FOODS EATEN BY 715 ADULT PERCH CAUGHT AT VARIOUS DEPTHS AND AT ALL SEASONS IN LAKE MENDOTA DURING 1915 AND 1916.

Depth at which caught (meters).	Fish.	Silt and débris.	Insect larvæ.	Insect pupæ.	Insect adults.	Mites.	Crayfishes.	Hyalella.	Ostracods.	Cladocera.	Copepods.	Snails.	Clams.	Oligochætes.	Leeches.	Plants.
0 to 10	5.3	4.1	33.0	4.0	1.0	1.9	7.0	9.5	0.4	21.2	0.4	3.1	0.7	1.0	1.0	3.6
10 to 15	0	9.5	38.1	8.7	.1	0	1.7	5.0	.1	27.1	.3	.2	1.6	2.5	0	3.6
15 to 20	0	11.6	37.4	8.4	.1	0	0	.8	.4	27.0	.1	0	3.4	3.4	0	7.6
Mean	1.8	8.4	36.1	7.[illegible]	.4	.6	2.9	5.1	.3	25.1	.2	[illegible].1	1.9	2.3	.3	4.9

TABLE 17.—NUMBER OF TIMES A PARTICULAR FOOD FORMED THE LARGEST ITEM, BY VOLUME, IN ALL PERCH CAUGHT AT THE SAME TIME AND DEPTH.[a]

[Percentages refer to numerical ratios, not to volume of food.]

Depth (meters).	Fish.	Silt and débris.	Insect larvæ.	Insect pupæ.	Insect adults.	Crayfishes.	Hyalella.	Cladocera.	Snails.	Oligochætes.	Plants.	Total records.
0 to 5	2	....	12	1	....	3	3	10	1	1	1	33
Per cent	6	....	36	3	....	9	9	30	3	3	3	....
5 to 10	....	....	11	....	1	1	1	4	....	....	....	18
Per cent	....	....	56.6	....	5.6	5.6	5.6	22.4	....	....	....	....
10 to 15	....	3	13	3	....	....	1	10	....	....	....	29
Per cent	....	10.4	44.8	10.4	....	....	3.5	34.5	....	....	....	....
15 to 20	....	4	14.5	.5	....	....	....	13	....	....	1	33
Per cent	....	12	43.5	1.5	....	....	....	49	....	....	3	....

[a] 687 adult perch caught during 1915 and 1916 in Lake Mendota are included.

TABLE 18.—FOOD OF SMALL PERCH COLLECTED IN SHALLOW WATER EAST OF BASE OF PICNIC POINT IN LAKE MENDOTA, 1916.

[All figures referring to food indicate percentage by volume; + means a trace.]

Date.	Perch.		Chironomus sp. larvæ.	C. fulviventris larvæ.	C. digitatus larvæ.	Procladius larvæ.	Orthocladius larvæ.	Tanypus decoloratus larvæ.	Tanypus monilis larvæ.	Plea minutissima larvæ.	Damselfly nymphs.	Mayfly nymphs.	Bætis nymph.	Cænis diminuta nymphs.	Agraylea multipunctata larvæ.	Enallagma hageni nymph.	Enallagma antennatum nymph.
	Number examined.	Average length (millimeters).															
July 7	10	29.6		1.6				6.9		0.1			+				
July 19	9	36.8	1.1	9.1		0.9		3.7								5.5	
Aug. 7	10	50.4		16.2								24.5					4.5
Aug. 24	10	61.4	2.5	1	2		0.4		7.5		3			1	25.5		

Date.	Corixa nymphs.	Chironomid pupæ.	Chironomid adults.	Hyalella azteca.	Ostracods.	Cyclops.	Nauplii.	Daphnia.	Chydorus sphæricus.	Eurycercus lamellatus.	Acroperus.	Ceriodaphnia.	Bosmina longirostris cornuta.	Pleuroxus procurvatus.	Filamentous algæ.	Plants.
July 7	1.5		0.1	15.3	0.1	43.3	2.7	0.1	8.9	11.8	0.2	0.1	6.5	0.5		
July 19				55.4	2.5	.2			.7	17.2		4.6		.3		
Aug. 7	.3			39.6	.8	.4		.5				13.9			0.9	0.2
Aug. 24		1		50.8		.3										1

TABLE 19.—FOOD OF SMALL PERCH COLLECTED ALONG NORTH SHORE OF OCONOMOWOC LAKE, 1916.

[All figures referring to food indicate percentage by volume; + means a trace.]

Date.	Perch.		Insect larvæ.	Chironomous sp. larvæ.	C. lobiferous larvæ.	C. fulviventris larvæ.	Orthocladius larvæ.	O. nivoriundus larvæ.	Palpomyia larvæ.	Tanypus sp. unknown larvæ.	Tanypus monilis larvæ.	Tanytarsus larvæ.	Procladius larvæ.	Cricotopus trifasciatus larvæ.	Probezzia glaber larvæ.	Cænis diminuta nymphs.	Dragonfly nymphs.	Damselfly nymphs.	Enallagma antennatum nymphs.
	Number examined.	Average length (millimeters).																	
June 14	13	57.8		8.4									0.3		3.4				7
July 15	10	47.3	1	.3				0.5		2	7.3	2.0							
July 17	10	46.2	2.5	.2		0.2					3.7					1.4	3.0	3.5	
Aug. 8	10	66.1							3.5	2.0	4.9					.3			
Aug. 14	10	48.5	4.3	.5	1.0	6.0	0.5		1.0	2.6	6.3			1.0		1.0			

Date.	Sialis infumata larvæ.	Caddisfly larvæ.	Agraylea larvæ.	Chironomid pupæ.	Palpomyia pupæ.	Crayfishes.	Hyalella azteca.	Ostracods.	Cyclops.	Ceriodaphnia.	Bosmina longirostris cornuta.	Eurycercus lamellatus.	Daphnia.	Pleuroxus.	Diaphanosoma.	Acroperus.	Chydorus sphæricus.	Physa.	Filamentous algæ.
June 14				4.7			18.7	0.3	32.7			0.5	18.8				2.3	0.6	1.4
July 15				2.0			42.8		10.4	1	1.5	10.0	1.5	0.9	1.5	9.1	2.0	.8	.6
July 17		1.0		1.2			37.3	+					36.1		9.0		.1		.5
Aug. 8	6.0		0.3	.5		20	61.8	.2									.3		
Aug. 14			28.0	.7	3.3		13.1	+	7.0	+	.3		.1		22.0		.5		.3

TABLE 20.—LOSS AND GAIN IN PERCH FED DIFFERENT FOODS FROM AUG. 19 TO SEPT. 18, 1916.

Food.	Number of perch fed.	Aug. 19		Sept. 18.		Per cent gain.		Per cent loss.	
		Average weight (grams).	Average volume (cubic centimeters).	Average weight (grams).	Average volume (cubic centimeters).	Weight (grams).	Volume (cubic centimeters).	Weight (grams).	Volume (cubic centimeters).
Liver and flour	[a] 3	2.104	2.40	2.501	2.46	19.89	2.5	....	....
Hyalella	3	1.856	1.76	2.296	2.3	23.70	30.68	....	....
Entomostraca	3	2.683	2.71	3.874	3.65	43.49	34.68	....	....
Earthworms	3	1.856	1.68	2.726	2.9	46.87	72.62	....	....
Insects, adult	3	2.152	2.07	1.643	1.7	....	....	23.65	13.04
Chironomid larvæ	3	2.099	2.00	2.836	2.9	35.11	45.0	....	....
Fish	3	1.944	1.91	2.380	2.45	22.42	20.41	....	....
Normal	2	3.232	3.20	3.850	3.9	19.12	21.87	....	....
Starved	[b] 3	1.205	1.26	.861	.76	....	....	28.54	39.68

[a] 1 died Sept. 6 on account of fouling of water.

[b] 1 died Sept. 11.

TABLE 21.—COMPARISON OF FOODS EATEN BY ADULT PERCH IN LAKE WINGRA AND IN LAKE MENDOTA, SHOWN BY MONTHS.

[The figures are percentages by volume and + means a trace; 350 perch were examined in Lake Wingra from March, 1916, to February, 1917. In Mendota, 499 were examined in 1915 and 188 in 1916. To obtain averages given for Lake Mendota the figures for 1915 were multiplied by 3 and averaged with those for 1916.]

LAKE WINGRA.

Month.	Fish and eggs.	Insect larvæ.	Insect pupæ.	Adult insects.	Mites.	Crayfishes.	Isopods.	Amphipods.	Ostracods.	Copepods.	Cladocera.	Snails.	Clams.	Leeches.	Oligochætes.	Plants, algæ.	Silt and débris.	$CaCO_3$ crystal.
January	41.5	46.6	......	......	......	......	......	1.0	......	......	5.4	......	......	0.6	......	3.0	0.6	......
February	35.3	34.3	......	4.0	0.2	......	4.2	8.9	1.9	2.1	.4	......	......	......	1.7	2.0	......	......
March	8.7	56.6	5.0	.1	......	......	......	5.8	......	.8	13.1	......	......	1.2	1.2	2.4	......	......
April	4.5	67.1	3.5	4.0	......	......	......	7.4	......	1.3	.6	1.7	......	.7	......	4.2	3.2	......
May	......	48.7	21.7	4.7	.1	......	......	3.6	......	......	13.8	.1	......	......	......	.8	2.0	......
June	1.0	54.0	30.4	.5	1.8	......	......	.2	.6	......	3.9	.8	0.5	.1	......	2.8	.4	......
July	10.3	63.2	22.9	......	......	......	......	.2	+	+	+	......	......	.3	+	.6	.5	......
August	41.9	14.9	25.3	......	......	......	......	......	......	......	2.0	......	......	......	......	7.5	3.4	......
September	7.4	15.4	15.6	......	.2	......	......	.2	......	+	54.7	......	......	......	......	3.9	.5	......
October	17.7	51.9	.9	1.9	......	......	......	3.2	+	......	16.1	.1	.1	......	......	5.7	1.1	......
November	16.0	58.1	......	3.5	......	......	......	1.7	.1	......	17.5	.5	......	......	......	1.7	1.8	......
December	......	96.5	......	......	......	......	......	......	......	......	1.5	......	......	2.0	......	......	......	......
Average	15.4	50.6	10.4	1.6	.2	......	.3	2.7	.2	.4	10.8	.3	.1	.4	.2	2.7	1.1	......

LAKE MENDOTA.

Month.	Fish and eggs.	Insect larvæ.	Insect pupæ.	Adult insects.	Mites.	Crayfishes.	Isopods.	Amphipods.	Ostracods.	Copepods.	Cladocera.	Snails.	Clams.	Leeches.	Oligochætes.	Plants, algæ.	Silt and débris.	$CaCO_3$ crystal.
January	......	18.6	......	......	......	......	......	0.8	0.6	1.4	51.0	......	1.1	......	0.9	11.7	11.3	......
February	......	23.2	......	......	......	......	......	......	2.3	.1	35.7	0.1	3.1	......	1.9	15.2	17.1	0.1
March	0.2	37.0	......	......	......	......	......	3.1	.4	.1	13.9	......	2.6	......	.3	16.3	21.6	2.0
April	7.7	25.6	1.6	1.1	2.8	......	......	6.8	......	.1	10.5	2.7	.2	2.8	1.7	14.2	17.3	2.3
May	5.3	41.5	2.6	1.4	3.0	1.8	......	7.0	......	.1	12.8	6.1	1.9	2.0	3.0	2.1	6.9	....
June	......	43.4	17.9	.8	.1	1.6	......	8.9	......	1.1	17.8	.5	3.2	.4	+	1.3	1.6	......
July	2.6	38.7	18.7	.3	......	7.6	......	2.6	......	......	20.8	.7	3.2	+	......	4.9	.3	......
August	......	34.2	2.4	4.5	......	4.4	......	3.6	.1	.1	40.9	1.9	.2	......	4.0	2.2	.2	......
September	2.6	36.5	4.9	.7	......	6.0	......	1.8	.1	.1	29.5	4.9	.9	......	5.6	5.1	1.3	......
October	......	8.6	15.7	......	......	.5	......	1.8	......	.1	60.2	1.4	1.4	.4	1.7	3.5	4.0	......
November	1.5	10.0	.1	2.3	......	......	......	3.9	.1	......	45.6	1.1	4.4	......	5.1	9.7	12.7	......
December	.4	16.8	......	......	......	......	......	.8	.8	.3	57.5	.8	......	......	2.5	5.5	13.2	......
Average	1.7	27.8	5.3	.9	.5	1.8	......	3.4	.4	.3	33.0	1.7	1.9	.5	2.2	7.6	9.0	.4

TABLE 22.—COMPARISON OF NUMBER OF PERCH EXAMINED FROM LAKE WINGRA AND FROM LAKE MENDOTA WHICH CONTAINED LITTLE OR NO FOOD, SHOWN BY MONTHS.

[Figures in parentheses indicate per cent of total catch.]

LAKE WINGRA, 1916.

Month.	Temperature (degrees centigrade).	Females.			Males.		
		Number caught.	Number nearly empty.	Number empty.	Number caught.	Number nearly empty.	Number empty.
January	....	14	0	0	2	0	0
February	....	16	0	0	0	0	0
March	....	7	0	0	9	0	0
April	10·6	25	0	0	28	0	8(15)
May	21·0	39	0	1(2)	1	0	0
June	20·5	28	0	0	11	0	0
July	29·6	23	0	0	19	0	0
August	26·3	15	0	5(12)	25	0	11(27)
September	15·9	21	2(5)	0	21	8(20)	1(5)
October	10·8	18	0	0	12	0	0
November	7·3	4	0	0	5	0	0
December	....	0	0	0	1	0	0

LAKE MENDOTA, 1915-16.

Month.	Temperature (degrees centigrade).	Females.			Males.		
		Number caught.	Number nearly empty.	Number empty.	Number caught.	Number nearly empty.	Number empty.
January	0·6	26	0	0	20	0	0
February	1·0	28	1(2)	0	16	0	0
March	2·2	22	0	0	37	0	0
April	3·8	28	0	4(6)	33	0	10(16)
May	9·8	49	1(1)	0	23	1(1)	0
June	14·4	28	2(2)	0	14	0	0
July	19·2	47	0	0	46	1(1)	0
August	19·3	29	0	1(2)	25	0	1(2)
September	17·2	32	0	0	13	0	0
October	13·4	22	0	0	28	0	0
November	4·9	25	0	1(2)	11	0	0
December	1·8	15	0	0	15	0	0

TABLE 23.—GAS CONTENT OF SWIM BLADDERS OF PERCH.[a]

Date.	Depth (meters).	Time left in oxygen-free water.		Gases in swim bladder.			Respiration quotient $\left(\frac{CO_2}{O_2}\right)$	Cubic centimeters of gases in water per liter.	
		Down.	On deck.	Per cent CO_2.	Per cent O_2.	Per cent N_2.		CO_2.	O_2.
Aug. 23	(b)			2.03	53.76	44.21	0.03		
	(b)			.68	44.64	54.68	.01		
	(b)			.71	51.12	48.17	.01		
	(b)			.91	47.83	51.26	.02		
Aug. 24	(b)			.24	50.97	48.79	.004		
	(b)			.33	41.17	58.50	.008		
	(b)			.108	44.51	55.39	.002		
	12	32 minutes	3 minutes	.833	28.12	71.05	.003	4.38	0.11
	12	do	7 minutes	.41	22.35	77.24	.02	5.51	.06
	12	42 minutes	3 minutes	.175	37.30	62.53	.005		
	12	do	6 minutes	.099	28.18	71.73	.003		
Aug. 26	(b)			.42	38.26	61.31	.01		
	(b)			.65	13.74	85.62	.04		
	13	1 hour	2 minutes	1.21	7.87	90.92	.15	4.64	.03
	13	do	5 minutes	.4	11.06	88.55	.03	4.12	.06
	13	do	8 minutes	.43	14.69	84.88	.03		
	13	do	10 minutes	.14	12.3	87.36	.01		
	13	1.5 hours	3 minutes	.211	24.24	75.50	.008		
	13	do	6 minutes	.31	19.66	80.03	.01		
	13	do	9 minutes	.31	22.51	77.18	.01		
	13	do	11 minutes	.11	17.90	81.99	.005		
Aug. 30	(b)			.64	18.51	80.85	.03		
	13.5	2 hours	6 minutes	.12	.73	99.15	6.08	7.21	.05
	13.5	do	9 minutes	.170	4.08	95.74	.04	5.98	.05
Aug. 31	(b)			.21	8.0	91.78	.03		
	13.5	1.1 hours	1 minute	.43	37.06	62.50	.01	5.67	.07
	13.5	do	8 minutes	.24	5.8	93.96	.04	5.15	.07
	13.5	2 hours	4 minutes	.21	4.17	95.62	.05		
	13.5	do	6 minutes	.044	28.21	71.75	.001		
	13.5	do	9 minutes	.05	27.09	72.86	.001		
	13.5	do	12 minutes	.26	20.51	79.23	.01		
Sept. 2	[c] 2			.33	28.24	71.43	.01	1.03	5.72
	2			.89	25.93	73.18	.03	1.54	4.87
	2			.62	34.12	65.26	.02		
	2			.71	25.65	73.64	.02		
	2			.24	32.43	67.33	.00		
	2			.25	25.06	74.68	.01		
Sept. 4	(b)			2.73	28.65	68.63	.09		
	(b)			.78	29.61	69.61	.02		
	[d] 13.5	½ hour	1 minute	1.20	24.78	74.02	.04		
	[d] 13.5	do	6 minutes	.25	25.31	74.44	.01		
	[d] 13.5	do	8 minutes	.43	9.96	89.61	.04	5.02	.24
	[d] 13.5	1 hour	6 minutes	3.0	14.19	82.81	.2		
	[d] 13.5	do	8 minutes	1.09	11.20	87.71	.1		

[a] Some individuals had been near the surface of Lake Mendota; others had been in the stagnant water below the thermocline, where there was practically no oxygen.

[b] Surface.

[c] These individuals were caught at a depth of less than 2 m. in University Bay.

[d] These individuals were kept on the deck of a boat in stagnant water pumped from 13.5 m.

TABLE 24.—PERCENTAGE OF GASES IN THE SWIM BLADDERS OF PERCH.[a]

Depth (meters).	Number of perch.	In stagnant water (hours).	Average CO_2.	Most CO_2.	Least CO_2.	Average O_2.	Most O_2.	Least O_2.	Average N_2.	Most N_2.	Least N_2.	Respiration quotient $\left(\frac{CO_2}{O_2}\right)$
Surface	21	....	0.81	3.0	0.11	36.21	53.76	8.0	62.97	91.98	44.21	0.02
12 to 13	5	½	.62	1.20	.25	22.10	28.12	9.6	77.27	89.61	71.05	.03
13	2	¾	.14	.17	.09	32.74	37.30	28.18	67.13	77.24	71.05	.004
13	8	1	.74	3.0	.14	14.27	37.06	5.8	84.83	93.96	62.50	.05
13	4	1½	.27	.31	.11	21.03	24.24	17.90	78.67	81.99	75.50	.01
13	6	2	.14	1.26	.04	14.16	28.21	.73	85.72	99.15	71.75	.01

[a] Some individuals were examined as soon as taken from surface water; others, after being left in the stagnant water below the thermocline.

TABLE 25.—SIZE OF PERCH AT SEXUAL MATURITY IN LAKES WINGRA AND MENDOTA, MARCH TO OCTOBER, 1916.

Lake.	Perch examined.		Size of perch (millimeters).		
	Number.	Sex.	Maximum.	Minimum.	Average.
Wingra	162	Male	178	113	134.9
Do	158	Female	180	118	137.7
Mendota	74	Male	187	115	156.6
Do	95	Female	201	120	167.6

TABLE 26.—SEX OF PERCH EXAMINED FROM VARIOUS DEPTHS OF LAKE MENDOTA DURING 1916.

Date examined.	Depth (meters).	Total catch.	Males.			Females.		
			Immature.	Ripe.	Spent.	Immature.	Ripe.	Spent.
Apr. 28	18	[a] 6	1	0	0	4	1	0
Do	3	[a] 380	1	376	0	0	3	0
Apr. 30	14.5	2	0	0	0	0	0	2
Do	12.5	6	0	0	0	0	3	3
Do	8.5	8	0	1	0	0	5	2
Do	5.0	11	0	8	0	0	0	3
May 2	15.0	12	0	0	0	1	7	4
Do	9.5	17	0	7	0	0	5	5
Do	4.5	23	0	22	0	0	0	1
May 6	18.0	7	0	1	0	0	1	5
Do	15.0	7	0	0	0	0	0	7
Do	7.7	8	0	3	0	0	0	5
Do	2.0	1	0	0	0	0	0	1
May 12	17.0	14	3	3	0	0	0	8
Do	15.0	32	0	11	0	2	0	18
Do	7	9	0	5	0	1	0	3
Do	3.5	53	1	51	0	0	0	1
Do	.5	5	0	0	0	1	0	4
May 17	17.0	47	4	12	2	1	0	27
Do	13.0	6	0	2	4	0	0	0
Do	4.5	0	0	0	0	0	0	0
July 13	19.0	81	0	1	51	0	0	29
Do	15.5	75	0	0	45	0	0	30
Do	12.0	53	0	0	18	0	0	35
Do	2.7	1	0	0	0	0	0	1
Do	3.2	0	0	0	0	0	0	0

[a] These nets remained in the water 14 hours; all others, 3 hours.

TABLE 27.—FISHES CAUGHT PER HOUR ON HOOKS AND LINES BAITED WITH MINNOWS, LAKE WINGRA, 1916–17.[a]

Date caught.	Temperature (degrees centigrade).	Depth (meters).	Number of hooks used.	Time (hours).	Perca falvescens.	Pomoxis sparoides.	Lepomis incisor.	Lepososteus osseus.	Micropterus salmoides.	Eupomotis gibbosus.
June 10	20.5	2–3	3	2.2	0	23.6	0.4	0.4	0	0
June 19	30.0	2–3	3	2.2	0	2.7	0	0	0	0
July 22	....	2–3	4	1.2	25.0	3.3	20.8	0	0	0
Do	....	2–3	4	3.3	4.5	.9	12.1	0	0	0
July 26	29.4	2–3	2	1.4	2.8	0	0	0	0	0
Do	....	3.1	2	2.5	0	1.2	.8	0	0	0
Aug. 5	....	2.8	3	4.0	.5	0	0	0	0	0
Aug. 20	27.0	3–2.5	1	2.4	0	.4	0	0	0	0
Aug. 29	26.8	1–2	3	3	0	0	0	0	0	0
Sept. 5	....	....	3	2.6	0	.3	0	0	0	0
Sept. 14	19.9	....	3	1.9	0	3.4	0	0	0	0
Sept. 23	14.5	....	3	3.4	3.2	0	0	0	0	0
Sept. 30	13.5	....	3	2.7	2.2	0	0	0	0	0
Oct. 7	14.8	....	3	3.7	0	0	0	0	0	0
Oct. 10	14.2	....	3	2.9	1.0	0	0	0	0	0
Oct. 11	13.7	....	3	.6	1.6	0	0	0	0	1.6
Oct. 14	12.3	....	2	2	2.1	0	0	0	0	0
Oct. 28	6.5	....	3	.7	1.4	0	0	0	0	0
Nov. 4	7.0	....	3	1.8	2.7	0	0	0	0	0
Nov. 11	6.7	....	3	1.0	0	0	0	0	0	0
Nov. 18	....	1.5	3	.5	0	0	0	0	0	0
Nov. 25	....	.8	3	1.2	0	0	0	0	0	0
Dec. 2	2.5	....	3	2.7	0	0	0	0	0	0
Dec. 23	....	1.5	3	3	0	0	0	0	0	0
Dec. 30	....	1.3	3	3	0	0	0	0	0	0
Jan. 2	....	1.0	3	.6	0	0	0	0	0	0
Do	....	2	2	1	2	0	0	0	0	0
Jan. 6	....	2	2	1	0	0	0	0	0	0
Jan. 20	....	1	3	2.5	0	0	0	0	0	0
Jan. 27	....	1	5	1.3	0	0	0	0	0	0
Do	....	2.5	2	2.1	2.5	0	0	0	0	0

[a] The lake froze over on Nov. 15; opened on Nov. 28; froze over again Dec. 10.

TABLE 28.—PERCH CAUGHT IN THREE 1-INCH MESH, 3 BY 60 FEET, GILL NETS, LAKE MENDOTA, AUG. 12 AND 13, 1916.[a]

2.9 m.[b]		7.5 m.[c]		Surface.[d]	
Time net in water.	Number.	Time net in water.	Number.	Time net in water.	Number.
8.35 a. m. to 12.33 p. m.	[e] 1	9.12 a. m. to 1.18 p. m.	[e] 112	9.00 a. m. to 1.00 p. m.	0
12.33 p. m. to 4.30 p. m.	3	1.18 p. m. to 5.18 p. m.	82	1.00 p. m. to 5.00 p. m.	0
4.30 p. m. to 9.00 p. m.	1	5.18 p. m. to 9.18 p. m.	71	5.00 p. m. to 9.10 p. m.	0
9.00 p. m. to 1.20 a. m.	1	9.18 p. m. to 1.43 a. m.	24	9.10 p. m. to 1.32 a. m.	0
1.20 a. m. to 5.00 a. m.	1	1.43 a. m. to 5.18 a. m.	72	1.32 a. m. to 5.10 a. m.	12
5.00 a. m. to 8.30 a. m.	1	5.18 a. m. to 9.18 a. m.	76	5.10 a. m. to 9.00 a. m.	0

[a] Thermocline at 8 to 9 m.; strong northeast wind.
[b] Set on bottom near shore.
[c] Set on bottom out in the lake.
[d] Set above the net set at 7.5 m.
[e] Taken ashore; all others were thrown back as soon as they were removed from the net.

TABLE 29.—PERCH CAUGHT IN THREE 1-INCH MESH, 3 BY 60 FEET, GILL NETS, LAKE MENDOTA, SEPT. 7 AND 8, 1916.[a]

2.8 m.[b]		9.5 m.[c]		Surface.[d]	
Time net in water.	Number.	Time net in water.	Number.	Time net in water.	Number.
10.10 a. m. to 2.04 p. m.	3	9.43 a. m. to 1.43 p. m.	1	9.49 a. m. to 1.52 p. m.	0
2.04 p. m. to 5.55 p. m.	2	1.43 p. m. to 5.37 p. m.	18	1.52 p. m. to 5.48 p. m.	0
5.55 p. m. to 10.18 p. m.	0	5.37 p. m. to 9.47 p. m.	39	5.48 p. m. to 10.08 p. m.	0
10.18 p. m. to 2.13 a. m.	0	9.47 p. m. to 1.47 a. m.	12	10.08 p. m. to 1.44 a. m.	0
2.13 a. m. to 6.03 a. m.	0	1.47 a. m. to 5.38 a. m.	13	1.44 a. m. to 5.48 a. m.	0
6.03 a. m. to 10.10 a. m.	0	5.38 a. m. to 9.43 a. m.	19	5.48 a. m. to 9.55 a. m.	0
....	....	9.43 a. m. to 1.43 p. m.	0	....	....

[a] Thermocline at 10.5 m.; strong northwest wind decreasing to moderate.
[b] Set on bottom near shore.
[c] Set on bottom out in the lake.
[d] Set above net set at 9.5 m.

TABLE 30.—PERCH CAUGHT IN THREE 1-INCH MESH, 3 BY 60 FEET, GILL NETS, LAKE MENDOTA, SEPT. 9 AND 10, 1916.[a]

2.7 m.[b]		11.2 m.[c]		Surface.[d]	
Time net in water.	Number.	Time net in water.	Number.	Time net in water.	Number.
11.45 a. m. to 4.00 p. m.	0	11.15 a. m. to 3.07 p. m.	[e] 60	11.25 a. m. to 3.25 p. m.	0
4.00 p. m. to 7.42 p. m.	0	3.07 p. m. to 7.15 p. m.	67	3.25 p. m. to 7.33 p. m.	0
7.42 p. m. to 11.32 p. m.	0	7.15 p. m. to 11.15 p. m.	0	7.33 p. m. to 11.20 p. m.	0
11.32 p. m. to 3.27 a. m.	0	11.15 p. m. to 3.06 a. m.	0	11.20 p. m. to 3.15 a. m.	0
3.27 a. m. to 7.37 a. m.	0	3.06 a. m. to 7.06 a. m.	[e] 39	3.15 a. m. to 7.20 a. m.	[e] 1
7.37 a. m. to 11.45 a. m.	0	7.06 a. m. to 11.15 a. m.	29	7.20 a. m. to 11.23 a. m.	0

[a] Thermocline at 10 to 11 m.; brisk south-southeast wind.
[b] Set on bottom near shore.
[c] Set on bottom out in the lake.
[d] Set above net set at 11.2 m.
[e] Taken ashore; all others were thrown back as soon as they were removed from the net.

TABLE 31.—PERCH INFECTED BY CERTAIN PARASITES IN LAKE MENDOTA, 1915–16, SHOWN BY MONTHS.

[Numbers in parentheses indicate percentage infected of total catch for a single month.]

Month.	Perch.		Parasites.						
	Number examined.	Number infected.	Nematodes in intestine.	Trematodes in intestine.	Tapeworm cysts in liver, peritoneum, etc.	Adult tapeworms in intestine.	Larval proteocephalids in intestine.	Acanthocephala.	Leeches (Piscola).
1915.									
March	41	27(66)	....	11(27)	20(50)	11(27)	4(10)	9(22)	....
April	28	24(86)	2(7)	....	15(53)	....	6(21)	4(14)	....
May	45	30(67)	10(22)	1(2)	16(35)	1(2)	2(4)	11(24)	....
June	60	28(47)	13(21)	....	16(32)	....	1(2)	5(10)	....
July	66	44(66)	13(20)	1(1)	42(96)	1(1)	....	1(1)	....
August	57	43(75)	10(22)	11(25)	29(72)	11(19)	....	....	....
September	43	38(90)	9(22)	....	35(87)	....	....	....	....
October	53	48(90)	10(20)	....	47(92)	....	2(4)	5(10)	....
November	37	36(97)	4(10)	....	32(86)	....	....	5(13)	....
December	36	27(75)	....	1(3)	20(55)	1(3)	....	....	1(3)
Average	46.6	34.5(76)	7.1(14)	2.5(3.8)	27.2(57.8)	2.5(5.2)	1.5(4.1)	4.0(9.4)	0.1(.3)
1916.									
January	10	10(100)	....	1(10)	10(100)	....	....	....	....
February	10	10(100)	1(10)	4(40)	9(90)	....	....	1(10)	....
March	20	19(95)	....	7(35)	18(90)	....	2(10)	5(25)	....
April	41	39(95)	....	24(60)	37(90)	....	1(2)	4(10)	....
May	29	25(86)	1(3)	11(38)	24(82)	....	2(7)	3(10)	....
June	16	15(94)	6(37)	1(6)	11(68)	....	....	....	....
July	33	32(97)	4(12)	....	31(94)	....	....	1(3)	....
August	15	15(100)	4(26)	1(6)	15(100)	....	1(6)	....	....
September	10	10(100)	2(20)	....	10(100)	....	....	....	....
December	15	12(80)	....	7(46)	12(80)	....	....	1(6)	....
Average	19.9	18.7(94.7)	1.8(11)	5.6(24)	17.7(80.4)	0	.6(2.5)	1.5(6.4)	0
Average for both years	33.2	26(85.3)	4.4(14.6)	4(14)	22.4(69)	1.2(2.6)	1(3.3)	2.7(7.9)	+(.1)

TABLE 32.—PERCH INFECTED BY CERTAIN PARASITES IN LAKE WINGRA, 1916–17, SHOWN BY MONTHS.

[Numbers in parentheses indicate percentage infected of total catch for a single month.]

Month.	Perch.		Parasites.					
	Number examined.	Number infected.	Nematodes.	Tapeworm larval cysts.	Tapeworms in intestine.	Proteocephalid larvæ.	Acanthocephala.	Leeches.
1916.								
March	17	13(76)	2(11)	11(65)	....	....	3(17)	....
April	54	49(90)	1(2)	49(90)	1(2)	1(2)	14(26)	....
May	41	38(92)	3(7)	38(92)	....	....	3(7)	....
June	40	34(85)	....	34(85)	....	....	2(5)	....
July	48	42(87)	....	42(87)	....	....	....	....
August	41	38(92)	1(2)	38(92)	1(2)	4(10)	2(5)	....
September	41	39(95)	7(17)	39(95)	....	....	1(2)	....
October	31	29(93)	1(3)	29(93)	....	2(6)	....	2(6)
November	26	23(84)	1(3)	23(88)	....	1(3)	....	....
December	2	0	....	....	....	....	....	....
1917.								
January	15	15(100)	15(100)	....	....	....	....	....
February	16	16(100)	16(100)	....	....	....	1(6)	....
Average	31	27(83)	1.3(2.7)	30(82)	.1(.3)	.7(1.7)	2.1(5.1)	.2(1)

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MARINE ALGAE OF BEAUFORT, N. C., AND ADJACENT REGIONS

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Contribution from the U. S. Fisheries Biological Station, Beaufort, N. C.

FOREWORD.

✤

The accompanying report by Prof. W. D. Hoyt is one of a series relating to the aquatic resources of the region adjacent to the biological station of the Bureau of Fisheries at Beaufort, N. C. This work comprises a scientific account of the marine algæ, commonly known as seaweeds, and is based on prolonged studies at the Beaufort station. The report is necessarily technical, but the author has endeavored to make it generally useful and has made the identification of the species clear by means of illustrations and simple keys. The result is a serviceable handbook for those who, for one reason or another, have occasion to identify the seaweeds.

The question may be asked, Why should the Bureau of Fisheries be interested in marine algæ? Excluding purely scientific considerations, there may be recalled the well-known fact that all animals depend on plants for food, and this is as true of water animals as of land animals. It matters not if a particular fish confines its diet to smaller fish or other animals rather than to plants. These smaller forms must feed upon something. At the end of the chain in every case there are plants of one kind or another, all engaged as busy little factories for the manufacture of food for fishes out of the inorganic materials which are otherwise useless or unavailable to fish. If we value fish and shellfish, we must be interested in the sources of their food; that is to say, in the seaweeds as well as in the innumerable minute plants of the sea and its bottom which do not come within the scope of this report.

It should not be overlooked that seaweeds have a direct economic importance. On other parts of the United States coasts, and more particularly in other countries, algæ are used in the natural state as food or as the basis for the preparation of food articles, such as gelatins. They constitute the raw materials from which are derived valuable commercial products, such as agar-agar, essential in bacteriological work; iodine, one of the most useful of all medical bases; and potash, a highly prized fertilizer.

The present report could not enter into a discussion of these economic relations, but it contributes the foundation of knowledge as to what the waters of the South Atlantic coast have in the way of algæ. It has been the labor of years, and, while the cost to the Government has been nominal, the results are of permanent value, especially in view of the fact that the algæ of the region have remained almost unknown.

It has not been possible for the author to consult every publication cited, and he has not had access to the type specimens of many of the species. Additional species will undoubtedly be found from time to time. These considerations, however, do not detract from the importance of the work.

H. M. Smith,
Commissioner of Fisheries.

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MARINE ALGÆ OF BEAUFORT, N. C., AND ADJACENT REGIONS.

⁂

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⁂

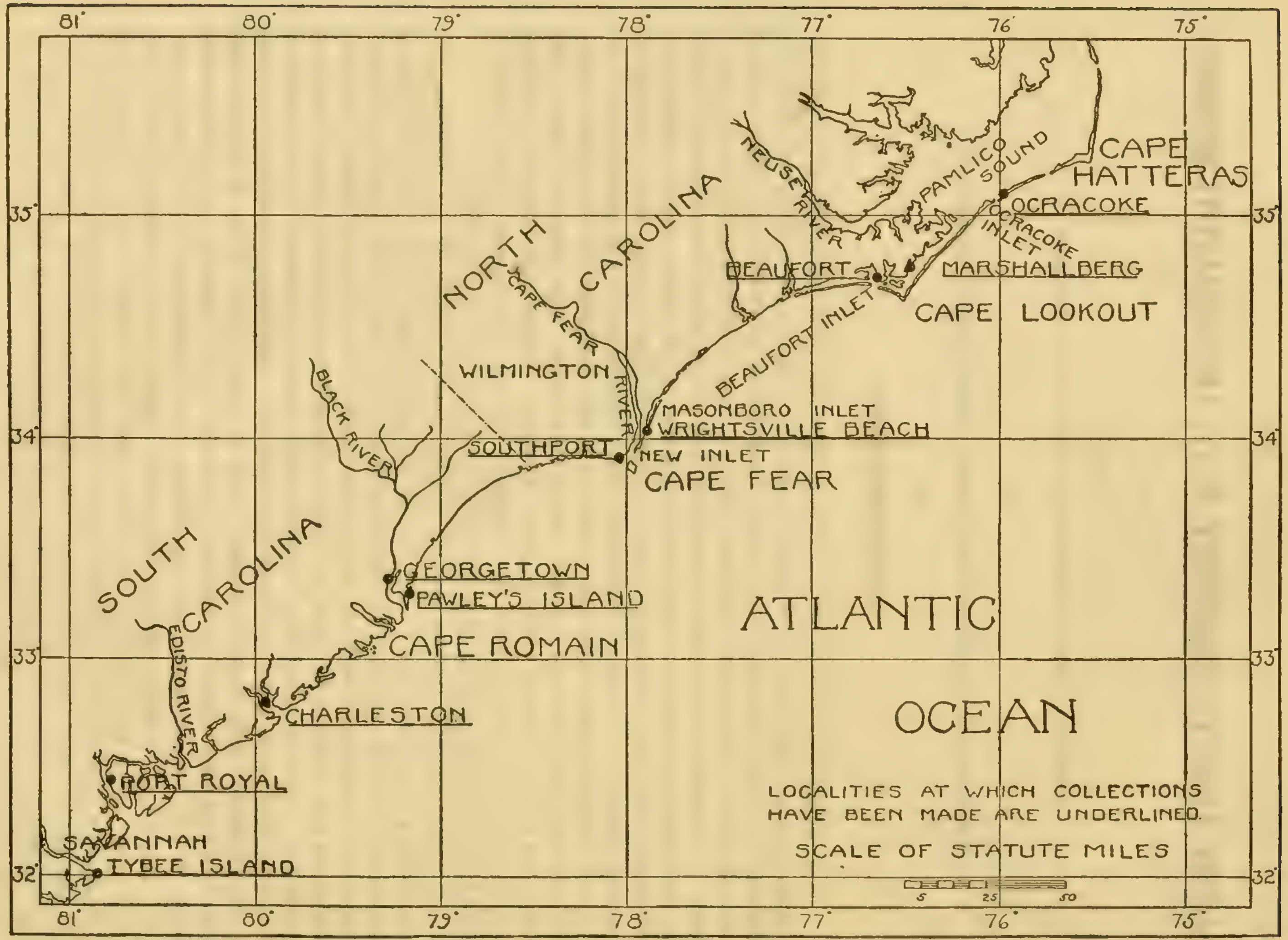
Contribution from the United States Fisheries Biological Station, Beaufort, N. C.

⁂

INTRODUCTION.

It has generally been believed that the greater part of our Atlantic coast is barren in respect to an algal flora. Although a number of species have been recorded from Norfolk, Va., and Charleston, S. C., and a few isolated collections have been made at points in North Carolina and elsewhere, Johnson (1900) recording between 25 and 30 species for Beaufort, it has generally been held that from Long Island Sound to Florida few individuals or species of algæ are to be found. The reason usually assigned for this sterility has been the supposed lack of places suitable for attachment afforded by the sandy coast of this region. While this belief is justified for the greater part of the area, the present studies have shown that it is not warranted for the entire region. One hundred and forty-two species and varieties have been observed here by the author, all but 10 of these being found at Beaufort. While this number is not large compared with 525 recorded for New England and 744 reported for Great Britain, a single locality yielding 132 species and varieties can not be called barren.

The area included in these studies extends from Ocracoke, N. C., to Tybee, Ga. (lat. from 35 to 32° N., map 1), but by far the greatest part of the work was done at Beaufort, N. C. (lat. 34° 43′ N.), only occasional visits being made to other localities. Studies in the region of Beaufort were made at the United States Fisheries Biological Station at that place from June or July to September or October during the years 1903–1909. Trips of a few days' duration were made to Beaufort by the author in May, 1907, and April, 1908, and monthly collections of all species observed were made by the laboratory staff from November, 1908, to June, 1909. Visits to regions other than Beaufort were made, as follows: Ocracoke, N. C., August, 1907; Wrightsville Beach, N. C., July, August, and September, 1909; Southport, N. C., Georgetown, S. C., and Pawley's Island (near Georgetown), August, 1909; Charleston, S. C., July and August, 1909; Port Royal, S. C., and Tybee, Ga., August, 1909. In addition to these algæ, the author has studied two small but interesting collections made by Lewis Radcliffe on the coral reefs offshore from Beaufort in August, 1914, and several collections made offshore in this region, principally in the vicinity of the coral reef, by the *Fish Hawk*, in July and August, 1915.


81°
80°
79°
78°
77°
76°
75°
35°
34°
33°
32°
CAPE HATTERAS
OCRACOKE
OCRACOKE INLET
PAMLICO SOUND
NEUSE RIVER
BEAUFORT
MARSHALLBERG
CAPE LOOKOUT
BEAUFORT INLET
NORTH CAROLINA
CAPE FEAR RIVER
WILMINGTON
MASONBORO INLET
WRIGHTSVILLE BEACH
SOUTHPORT
NEW INLET
CAPE FEAR
BLACK RIVER
SOUTH CAROLINA
GEORGETOWN
PAWLEY'S ISLAND
CAPE ROMAIN
ATLANTIC
OCEAN
EDISTO RIVER
CHARLESTON
PORT ROYAL
SAVANNAH
TYBEE ISLAND
LOCALITIES AT WHICH COLLECTIONS HAVE BEEN MADE ARE UNDERLINED.
SCALE OF STATUTE MILES
5
25
50

Map 1.—Region included in these studies, showing localities at which collections were made. (The locations of Masonboro Inlet and Wrightsville Beach should be reversed on the map. The collections in this place were made in Banks Channel, just south of Moores Inlet, about 1.5 miles north of Masonboro Inlet.)

In the preparation of the present report three objects have been kept in view: (1) Only occasional collections have previously been made on the coast of our southern States. While the algal flora of New England and Long Island has been studied with some thoroughness and the Florida coast has received considerable attention, the area between these regions has been almost untouched in recent years. Although the present work makes no pretense of being a taxonomic contribution, the effort has been made to present as complete an account as possible of the algal flora of the region, with remarks on species affording interesting comparisons with the same species found in other regions. (2) Little is known of the conditions of algal growth and of the factors limiting their distribution in space and in time. Notes have been made on the conditions observed at Beaufort, and some interesting effects of these conditions have been recorded. It would be desirable to have a detailed and thorough study of the conditions made here. (3) No work suitable for American collectors who are not trained students of algæ has appeared in recent years, and no such work has ever been written for the algæ of our southern coast. Although this lack has been partly filled by Collins's excellent treatment of the Chlorophyceæ (1909, 1912, 1918) and key (1918a) and Miss Tilden's work on the Myxophyceæ of North America (1910), the need still exists for a special account of the algæ of this region. With this object in mind, the present report has been written as simply as possible. Technical terms have been avoided whenever the meaning could be expressed otherwise without too great circumlocution and without sacrifice of accuracy. Nearly every species has been illustrated by a photograph or drawing, since an illustration will often give, to one not a special student of the algæ and even to the trained algologist, a better idea of the species than pages of description. Two keys have been prepared, one (an artificial key to genera) based as far as possible on superficial, easily observed characters, the other (a natural key to divisions, orders, etc.) showing the diagnostic characters which warrant the placing of the different forms in their respective groups.

All photographs and, except where otherwise stated, all drawings are original, nearly all the photographs being made from living plants and all the drawings being made with a camera lucida. In the descriptions of the various groups and in the natural key free use has been made of current works, especially those of Engler and Prantl (1897–1911), De Toni (1889–1907), and Collins (1909, 1912). The descriptions of the species, however, are based in part on specimens observed by the author, including those found at Beaufort and those in American herbaria which were accessible to him. In using the artificial key to genera and the keys to species, it should be borne in mind that these have been prepared for the particular genera and species mentioned in this work, and if used for algæ of other regions may lead the student astray. Even in this region these keys may cause confusion if genera and species other than those mentioned should be found. A collector should, therefore, always carefully compare his specimens with the descriptions before venturing to assign them names. The gross measurements of the size of species should not be taken too strictly, the figures given being the limits of specimens observed by the author or for which a record has been seen.

It will be noticed that the descriptions of many of the species are incomplete in that no mention is made of male plants or organs. This is due to our imperfect knowledge of these plants, since, partly because of their inconspicuousness and partly because of their greater scarcity, male plants and organs have been studied much less than have the other forms of plants and organs of reproduction. Svedelius (1908, 1912) has shown that, in Martensia and *Delesseria sanguinea*, the male plants have an exceedingly short duration, in the latter species not more than one month. Miss Dunn (1917) has called attention to the fact that, in *Dumontia filiformis* on the coast of Maine, the male plants are found only during a few weeks in the spring. A similar scarcity of male plants has been observed by the author for many species at Beaufort. In spite of extensive searches for them, no male plant of *Gracilaria confervoides* has been observed, and none of *Gracilaria multipartita* has been found in the harbor; only one male plant of Hypnea has been found among the hundreds examined; and male plants of Chondria are rare. Many other instances of the same kind might be given. While further search might show these to be more abundant than is indicated here, it seems to be true that, with the exception of a few species, male plants and organs are much scarcer than are the other forms of plants and organs. Because of this fact, anyone finding male plants or organs of a species in which they are not described in this work, should save these for study, or should send them to some other student of the algæ.

Among the Phæophyceæ and Rhodophyceæ all determinations have, as far as possible, been verified by comparison with type or authentic material. Among the Myxophyceæ the determinations have been made entirely and among the Chlorophyceæ they have been made largely by Mr. Frank S. Collins. Under each species references are given to the original place of publication; to the most recent general account of the algæ, the Sylloge Algarum of De Toni (1889–1907); and to the works of Harvey (1852–1858), Farlow (1882), Collins (1909, 1912, 1918), and Miss Tilden (1910), these being the publications of a more or less general nature dealing with North American algæ. In a few cases other references of special interest are given. Citations are given, also, to the two principal sets of American algæ, the Algæ Americanæ Boreales Exsiccatæ (A. A. B. Ex.) of Farlow, Anderson, and Eaton, and the Phycotheca Boreali-Americana (P. B.-A.) of Collins, Holden, and Setchell. With some exceptions, where the works cited were not available, all references have been verified. The arrangement used follows, in most respects, that of Engler and Prantl (1897–1911),[a] except in the Chlorophyceæ, where Collins (1909, 1912, 1918) has been followed. The system of nomenclature follows the Vienna and Brussels rules except in the naming of the divisions, where Chlorophyceæ, etc., have been used. The retention of these names seems justified by usage, convenience, and uniformity, and, although not yet acted upon by any congress, seems to come under the principles of nomina conservanda.

Those wishing to know more than is given here about the structure of the algæ mentioned should consult Oltmanns (1904–5) and Engler and Prantl (1897–1911), where are summed up the main facts about the structure of algæ known at the time of their publication.

A work of the present nature necessarily has a limited usefulness and should be replaced by an account of the algæ of our entire coast. If the present report contributes toward the preparation of the larger work and serves in the meantime to forward the study of the algæ of our Atlantic coast, it will have served its purpose.

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[a] While this arrangement is inconsistent and apparently wrong in many respects, we have not yet sufficient knowledge to warrant a complete revision, and must, accordingly, use it until we obtain more information about the life histories and structures of the various groups of algæ.

The author takes pleasure in acknowledging his indebtedness to those who have helped him in the present study. To Frank S. Collins, North Eastham, Mass., and to Dr. Marshall A. Howe, the New York Botanical Garden, he is especially indebted for assistance in the determination of species given throughout the progress of this work and for much helpful advice and information about the distribution of species and about doubtful points. He is indebted to Dr. N. L. Britton for facilities for studying the algæ in the New York Botanical Garden and for the use of Plates CXV–CXIX, and to other members of the staff of this institution for assistance during his work in the library there. To Prof. W. G. Farlow, Harvard University, he is indebted for assistance in the determination of species and for the privilege of studying the algæ in his herbarium; to Prof. D. S. Johnson, the Johns Hopkins University, for facilities of laboratory and library furnished for the study of the Beaufort algæ; to Mrs. Margaret H. Y. Hoyt, for assistance with the drawings used in this work and with the preparation of the manuscript. To all of these and to others who have helped him in various ways the author wishes to express his grateful appreciation of their assistance.

PART I. GENERAL ACCOUNT OF THE REGION.

LOCATION AND DESCRIPTION OF BEAUFORT HARBOR.

The town of Beaufort lies at latitude 34° 43′ N., longitude 76° 40′ W., about 19 km. (12 miles) northwest from Cape Lookout and 120 km. (75 miles) southwest of Cape Hatteras. (See map 2.) South and west of the town stretches the harbor, a large body of water communicating with the ocean by a wide inlet between Shackleford Banks and Bogue Banks. From the harbor near this inlet extend Bogue Sound to the west and Back Sound to the east, separating the mainland from Bogue Banks and Shackleford Banks, respectively. Extending northwest from Beaufort Harbor lies the body of water known as Newport River, with several creeks, receiving frequent inflows of fresh water. A somewhat similar body of water extends northward from Back Sound. The bottom throughout this region is composed of sand, mud, or shells, and offers no conditions favorable for the growth of algæ.

The beaches of Bogue and Shackleford Banks are flat, sandy stretches. Shackleford Beach and the greater part of Bogue Beach are destitute of algæ. Algæ are, however, frequently found on Bogue Beach for a distance of about 1.6 km. (1 mile) west from the inlet. Here, after storms, are found great masses of algæ washed on the beach or lying in the water along the shore. Many of the plants found here, in all likelihood, have been carried out from the harbor by the receding tide; others have almost certainly been washed in from the coral reefs lying offshore, since several species found elsewhere only on the beach were dredged from these coral reefs; while a few species, represented only by specimens from Bogue Beach, may have come from points farther south, some of these being unknown elsewhere north of Florida or the West Indies, and possibly being brought here by the Gulf Stream from that region or from some of the intermediate submerged coral reefs.[a]

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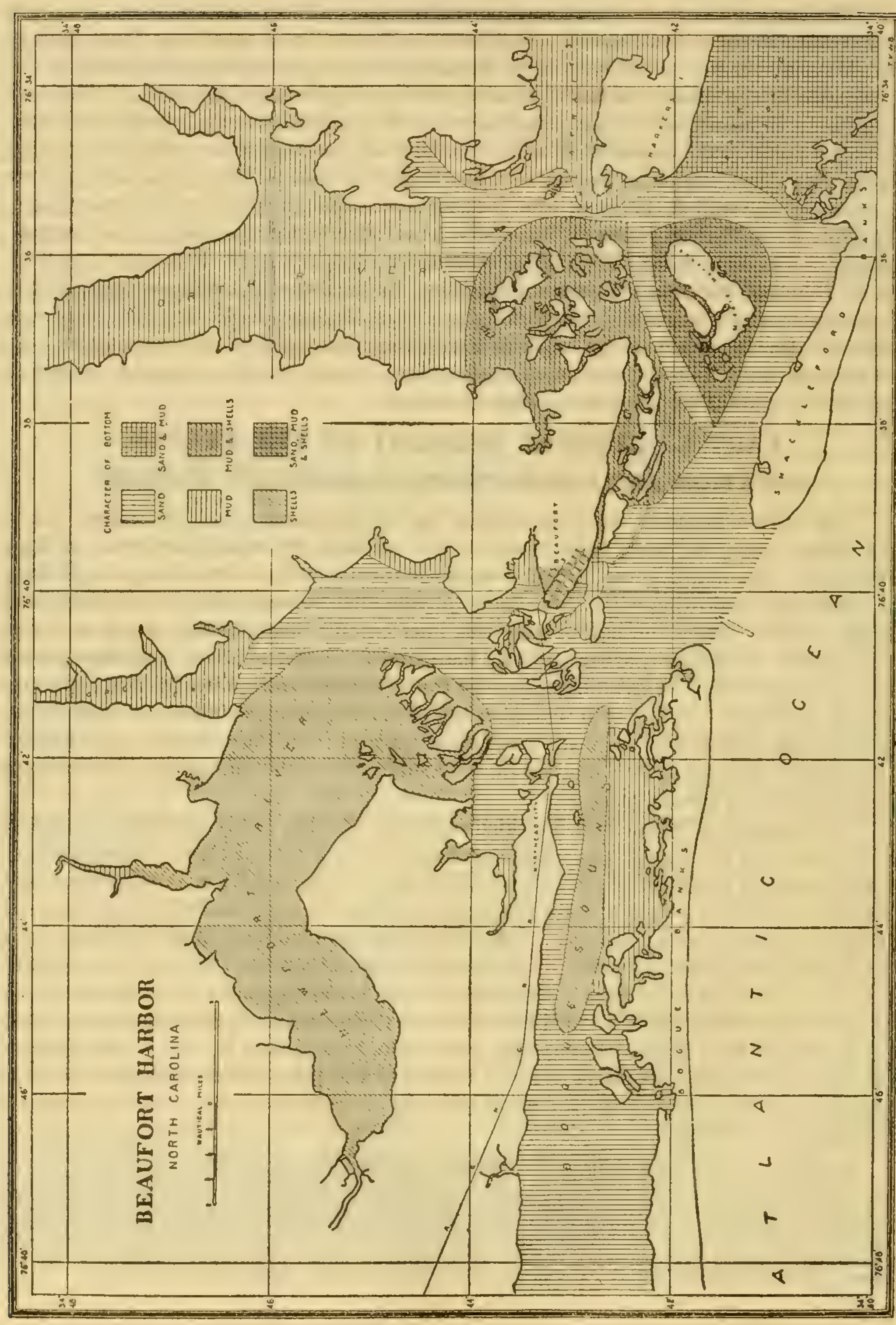
[a] While species found only on the beach can not strictly be included in the flora of Beaufort, they are treated as a part of the algæ of this region. This has seemed proper, since it is very probable that some of these have come from the coral reefs offshore, and it is impossible to distinguish between the species that come from these reefs and those that are brought from other regions. Moreover, in view of the algæ found on these reefs, it is unsafe to assume that any species observed in this region has come from a more distant point. Such species may be found at any time by collectors here or at other places, and it is entirely possible that some of these, even if they do not now occur at Beaufort, may establish themselves here, either in the harbor or on the coral reefs offshore. These species are included in the total number given for the region, but are enumerated in a separate list.

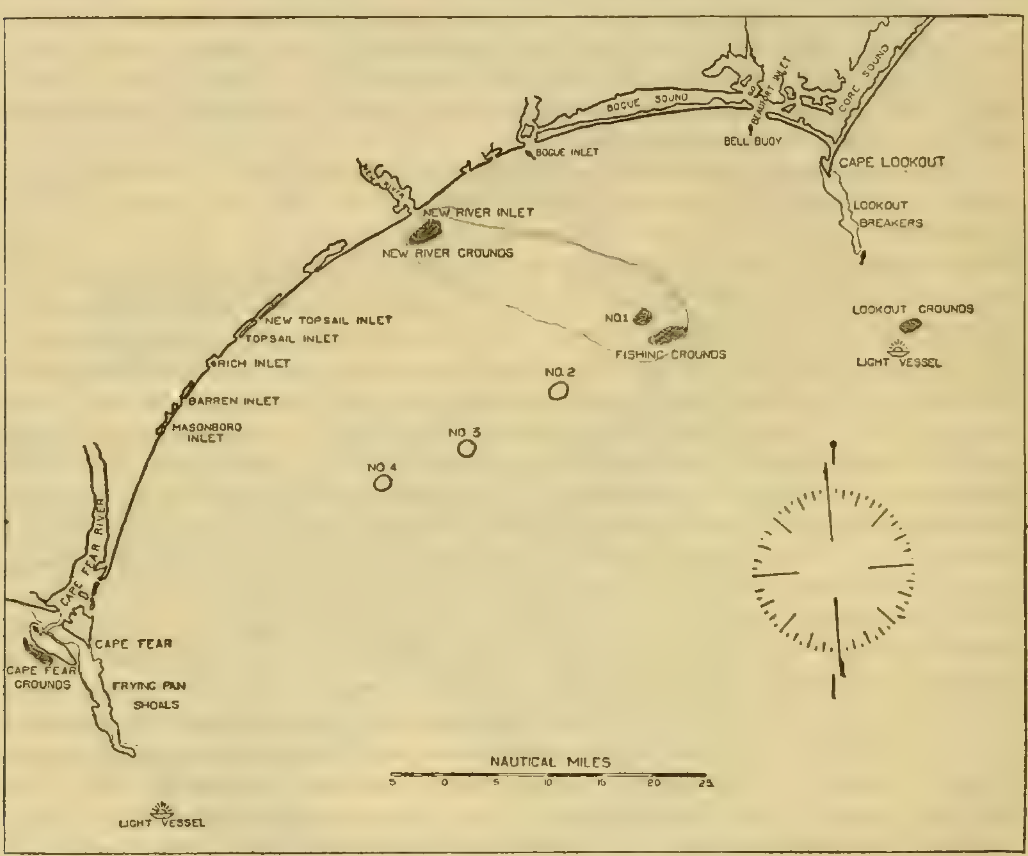

BEAUFORT HARBOR
NORTH CAROLINA
NAUTICAL MILES
CHARACTER OF BOTTOM
SAND
SAND & MUD
MUD
MUD & SHELLS
SHELLS
SAND, MUD & SHELLS
NORTH RIVER
NEWPORT RIVER
BEAUFORT
MOREHEAD CITY
BOGUE SOUND
BOGUE BANKS
SHACKLEFORD BANKS
HARKERS I.
ATLANTIC OCEAN
76° 34'
76° 40'
76° 46'
34° 40'
34° 48'
36
38
42
44
46

Map 2.—Beaufort Harbor. Water areas shaded to show nature of bottom.

Hourly observations of the current were made by the U. S. Coast and Geodetic Survey on Cape Lookout Shoals Light Vessel from June 7 to September 1, 1912. These showed that, at this place, the mean current, freed from tidal influence, flowed S. 87° E. with a velocity of 723 m. per hour (0.39 knot) from June 7 to July 5, and N. 85° E. with a velocity of 1.372 km. per hour (0.74 knot) from July 6 to September 1. From this it appears that the Gulf Stream, following the general direction of the coast, has its western edge, on an average, during the summer season, somewhat westward from Cape Lookout Shoals Light Vessel (see map 3), and about 55 km. (30 nautical miles) offshore from Beaufort Inlet. No observations have been made for this region at other times of the year, but the exact location of the Gulf Stream will, of course, vary considerably at different seasons and even on different days of the same season, depending on the direction and strength of the wind.

Lying offshore are a number of submerged coral reefs (see map 3) which offer some of the most interesting conditions found in this region. These have been described by Radcliffe (1914). The outer reefs lie from about 29 to 39 km. (16 to 21 nautical miles) offshore at a depth of 24 to 28.8 m. (13.25 to 16 fathoms), while the two inner ones lie, respectively, about 3.3 and 6.5 km. (1.8 and 3.5 nautical miles) offshore at a depth of 8 to 13.5 m. (4.5 to 7.5 fathoms). The largest of these, the "Fishing Grounds," was visited by the author on board the *Fish Hawk* in May, 1907, two days being spent there and 22 hauls being made with the dredge over the entire observed reef. This lies about 39 km. (21 nautical miles) offshore, about 22 km. (12 nautical miles) inshore from the average summer location of the western edge of the Gulf Stream, at a depth of 24 to 25.5 m. (13.25 to 14 fathoms). At the time of this visit the observed length was about 1.85 km. (1 nautical mile) and the observed width was about 900 m. (0.5 nautical mile). Observations made by Radcliffe in the summer of 1914 indicate, however, that this reef is many times larger than was previously known. It is now believed to include Station No. 1 (see map 3) extending many kilometers in the direction of New River Inlet and being several kilometers wide. The lower part is composed of old, dead coral masses, hard and densely packed, with the surface fairly smooth, forming a sort of coral rock, penetrated and honeycombed by numerous worms and molluscs. On and in this substratum were found many hydroids, corals, sponges, Gorgonias, Echinoderms, Lamellibranch molluscs, Crustacea, worms and Ascidians, together with numerous algæ. Over the reef swam abundant fish, mainly sea bass (*Centropristes striatus*), the sailors catching these as fast as they could pull them in. The bottom around the reef was composed of sand and broken coral, and, except for one large, apparently unattached mass of *Zonaria flava*, all signs of life (including the fish) ceased as soon as its border was passed. Although living coral was abundant on top of the reef, there was no evidence that this is growing toward the surface, the depths recorded on the four visits made by the *Fish Hawk* to this place in 1902, 1907, 1913, and 1914 being almost identical.

Some observations made by Radcliffe on board the *Fish Hawk* in the summers of 1913 and 1914 disclose interesting conditions in the vicinity of this reef. Other reefs seem to be present at various points along the shore, and coral and algæ were found abundantly. Over considerable areas at many points offshore the bottom seemed smooth and hard—apparently consisting of rock as smooth as a floor—and bore scattered specimens of algæ. Offshore from New River Inlet there was found an abundance of *Dictyopteris polypodioides* growing in scattered patches separated by sand. This growth was observed partially covering the bottom over an area extending at least 22 km. (12 nautical miles) alongshore eastward from the inlet, and from near the shore to at least 13 km. (7 nautical miles) offshore, at a depth of 5.8 to 11.6 m. (3 to 6 fathoms). The actual area occupied by this growth was certainly larger than this, since the inner limit was nearer the shore than the vessel could approach, and the outer limit was in water too deep for observation. Moreover, it was found in abundance in July, 1915, offshore from Browns Inlet, about 25 km. (16 miles) northeast of New River Inlet (toward Beaufort), and it may extend westward also from New River Inlet. Its presence here is in striking contrast to the barren bottom observed at other inlets and along most of the shore and raises an interesting question as to the substratum to which it is attached. This must be something other than sand, but its nature was not determined. That rock of some sort is present over considerable portions of the bottom is indicated, however, by the observations of Radcliffe mentioned above and by the further fact that there was evidence of corals and algæ on the bottom in the Gulf Stream about 70 km. (38 nautical miles) offshore at a depth of about 115 m. (60 fathoms).


BOGUE SOUND
BEAUFORT INLET
CORE SOUND
BELL BUOY
BOGUE INLET
CAPE LOOKOUT
LOOKOUT BREAKERS
NEW RIVER
NEW RIVER INLET
NEW RIVER GROUNDS
LOOKOUT GROUNDS
LIGHT VESSEL
NEW TOPSAIL INLET
TOPSAIL INLET
NO.1
FISHING GROUNDS
RICH INLET
NO.2
BARREN INLET
MASONBORO INLET
NO.3
NO.4
CAPE FEAR RIVER
CAPE FEAR
CAPE FEAR GROUNDS
FRYING PAN SHOALS
NAUTICAL MILES
5 0 5 10 15 20 25
LIGHT VESSEL

MAP. 3.—Location of known "fishing grounds," mostly submerged coral reefs, offshore from the region of Beaufort, N. C. (From Radcliffe, 1914.) The largest of these, the "Fishing Grounds," is larger than shown here, extending from New River Inlet and probably including Station No. 1. Algæ referred to as coming from coral reef offshore were gathered from this reef.

Similar "fishing grounds" occur off other portions of our coast. To the south of this region there are listed by Goode and associates (1887, pp. 53–55, chart 15) 13 fishing grounds off the coast of South Carolina, 3 off the coast of Georgia, and 1 off the northern coast of Florida. These lie at various distances from the shore at depths of 13.5 to 35.7 m. (7 to 18 fathoms) and have sizes varying from a reef about 800 m. (0.5 mile) square to a circular one having a diameter of 11 to 16 km. (7 to 10 miles). The bottoms are variously described as consisting of rock, limerock, coral rock, coral, shells, or sand, and all are said to bear gorgonian corals and sponges. Under these conditions we can be sure that algæ also occur there.

To the north of Beaufort, rocks are said to occur off the coast of Virginia, and fishing grounds with rocky or sandy bottoms are listed by Goode and associates (1887, pp. 46–51, charts 12–13) off the coasts of Delaware, New Jersey, and the south shore of Long Island, connecting with those off the coast of New England.

These conditions—the existence of a fairly continuous line of submerged rocky reefs extending from subtropical to cold northern waters, the subtropical nature of the flora found on the reefs offshore from Beaufort, the apparent existence of algæ and corals on the bottom in the Gulf Stream, together with the northern course of this stream—seem to furnish excellent means for subtropical species of plants and animals to travel up our coast. Such species can live offshore in water warmed by the Gulf Stream, and, if the local conditions permit, may establish themselves temporarily or permanently on the mainland. These facts probably explain the occurrence of several of the species found in Beaufort Harbor and probably account for all the species found on the beach.

It would be interesting to discover how far north of Beaufort subtropical species may occur. A thorough survey of these reefs, including their geology, oceanographical conditions, flora and fauna, would undoubtedly yield facts of great interest and importance.

GENERAL ACCOUNT OF THE ALGÆ.

The intermediate location of this region gives a flora of considerable interest, containing both northern and southern elements, with southern species predominating. Considering the flora as a whole, of the 142 recognizable species and varieties recorded, 133 have been obtained in proper condition and amount for determination. Of this number, 62 (46.6 per cent) are found in New England, and 91 (68.4 per cent) are known to occur in the Florida-West Indies region. In the different divisions the relative numbers are as follows:

Division.	Species and varieties of algæ identified in Beaufort region.					
	Total.		Recorded for—			
			New England.		Florida-West Indies.	
	Number.	*Per cent.*[a]	*Number.*	*Per cent.*[b]	*Number.*	*Per cent.*[b]
Myxophyceæ	10	7.5	7	70.0	8	80.0
Chlorophyceæ	25	18.8	12	48.0	21	84.0
Phæophyceæ	27	20.3	12	44.4	13	48.1
Rhodophyceæ	71	53.4	31	43.7	49	69.0

[a] Per cent of total number identified in Beaufort region.
[b] Per cent of total number in the division identified in Beaufort region.

Of the 84 genera found in the Beaufort region, 24 genera and 46 species reach here their northern known limit on our coast (Tables 5, 7), while 4 genera and 9 species reach their southern known limit in this region (Tables 6, 7). Furthermore, 20 species not previously recorded for North America have been found, 11 of these being new. Of the 133 identified species and varieties, 78 (58.6 per cent) are recorded for Europe, and 41 (30.8 per cent) for the Pacific coast of North America.

The 46 species reaching their northern limit here (Table 5) have been found as follows:

Growing in Beaufort Harbor	16
Growing only on coral reef	16
Found only on Bogue Beach	11
Known only from other localities	3

The 9 species reaching their southern limit here (Table 6) have been found as follows:

Growing in Beaufort Harbor	7
Growing only on coral reef	1
Known only from other localities	1

The 20 species which are new to North America (Table 7) have been found as follows:

Growing in Beaufort Harbor	6
Growing only on coral reefs	12
Found only on Bogue Beach	1
Known only from other localities	1

The most striking characteristic of the flora is the preponderance of red and the paucity of blue-green algæ. The large number of red algæ indicates the southern relationship of the flora; but here also is found a large northern element, as was shown above. The small number of blue-green algæ is not easily explained. At other places the number is probably greater than is indicated here; indeed, the author saw large masses of undetermined Myxophyceæ covering the rocks of a jetty near Georgetown, S. C. At Ocracoke, N. C., also there were observed masses of blue-green algæ densely covering the ocean beach just beyond the high-tide line for many square meters and covering the wharf piles between tide lines. The number of species found in these places was not large, but other species may have been present. At Beaufort, N. C., however, although one species (*Lyngbya confervoides*) is very abundant, covering walls and jetties for considerable areas between tide lines, repeated careful searches have failed to discover any other species in abundance and have yielded a total of only five species growing in the harbor.

The relative richness, in other respects, of the Beaufort flora as compared with the flora of other localities is shown by the fact that of the 142 species and varieties recorded for the region 132 were found at this place. While a part of this numerical preponderance is undoubtedly due to the fact that Beaufort has been studied more thoroughly than other localities, a large part is due to an actually greater richness of the flora of this region. At no other locality has the author found anything to approach the number of individuals or of species that may be observed at Beaufort on a single collecting trip at any time during the summer.

The 124 identified species and varieties recorded for Beaufort have been found as follows:

	Number.	Per cent.
Growing in the harbor (Table 1)	77	62.1
Growing only on the coral reefs (Table 2)	29	23.4
Occurring only on Bogue Beach (Table 3)	18	14.5

As with other plants, two factors determine the algal flora of any region. First, the conditions prevailing at any place naturally exclude all species which are not able to grow under those conditions; second, of the species which are able to grow in any locality, only a part find access to the region and arrive there under conditions favorable for obtaining lodgment. We may be certain that there are hundreds of other species that could grow at Beaufort if they should be carried there. Since, with marine algæ, artificial means of transport are usually excluded, the flora which we find in any locality favorable for the growth of algæ is determined to a considerable extent by the direction of the currents bringing fruiting plants, fragments, or spores of algæ from other regions. Occasionally, however, an alga may be introduced into a region by artificial means. On one occasion there was found in Beaufort Harbor a fragment of *Halimeda* sp. This seemed a very interesting discovery until it was noticed that there was in the harbor at that time a boat from the West Indies bearing tropical shells and other marine objects for sale. To this boat we may confidently ascribe the presence of the Halimeda. Although this species of alga did not establish itself at Beaufort, its presence there showed the possibility of the distribution of algæ by artificial means of transport.

There is evidence that at least one species has established itself at Beaufort during the progress of these studies. *Rosenvingea orientalis*, known elsewhere in North America only from Guadaloupe and from Wrightsville Beach, N. C., was first found on Bogue Beach in September, 1905, and was not observed in the harbor during that year. The following summer, however, this species was found growing between Fort Macon jetties and on the sea buoy, and in the summer of 1907 it was found on Shackleford jetty as well as on Fort Macon jetties. The records indicate similar facts for a few other species, but are not sufficiently complete to warrant conclusions about them. Miss Dunn (1917) has presented convincing evidence showing that one species of algæ, *Dumontia filiformis*, appeared on the coast of Maine and established itself there between the years 1909 and 1913. This species seems now to have spread in considerable abundance along a large part of the New England coast.

Several species have been found growing in Beaufort Harbor on only one occasion. Such species, while obtaining a foothold, seemed unable to maintain themselves, perhaps because of changing conditions. These may be expected to reappear at any time and may establish themselves. Other species have been found only occasionally, being represented by scattered individuals. Such species seem to be living near the limit of their endurance and may appear and disappear as conditions become more or less favorable. Still other species, not yet observed here, may be expected to appear whenever chance currents bring them to this region under conditions favorable for their obtaining a foothold.

FLORA OF BEAUFORT HARBOR.

Considering, first, the 77 species and varieties found in Beaufort Harbor, the number of these in the different divisions is:

	Number.	Per cent.
Myxophyceæ	5	6.5
Chlorophyceæ	17	22.1
Phæophyceæ	15	19.5
Rhodophyceæ	40	51.9

These are distributed throughout the year as follows:

	Number.	Per cent.
Summer flora only	40	51.9
Spring flora only	22	28.6
Spring and summer floras	4	5.2
Perennial	11	14.3

The strictly summer flora is distinctly southern in its character, but even this has a decided northern element. Of the 40 species and varieties included here, 30 (75 per cent) occur in the Florida-West Indies region, while 17 (42.5 per cent) are found in New England. Of these 17 forms recorded for New England, however, all except four are of general distribution, occurring in the Florida-West Indies region also. The distribution of this summer flora in the different divisions is as follows:

	Number.	Per cent.
Myxophyceæ	4	10.0
Chlorophyceæ	7	17.5
Phæophyceæ	7	17.5
Rhodophyceæ	22	55.0

The strictly spring flora, on the contrary, is distinctly northern, of the 22 species and varieties recorded, 20 (90.9 per cent) being found in New England and only eight (36.4 per cent) being known from the Florida-West Indies region. Its northern character is further shown by the fact that red algæ do not predominate here, the number in the different divisions being:

	Number.	Per cent.
Myxophyceæ	0	0.0
Chlorophyceæ	8	36.4
Phæophyceæ	6	27.2
Rhodophyceæ	8	36.4

The four species common to the spring and summer flora are red algæ. All of these are found in the Florida-West Indies region, while three occur in New England also.

Of the 11 perennial species, all are found in New England while nine occur in the Florida-West Indies region also. The numbers in the different divisions are:

	Number.	Per cent.
Myxophyceæ	1	9.10
Chlorophyceæ	2	18.18
Phæophyceæ	2	18.18
Rhodophyceæ	6	54.54

It is probable that further search would increase the number of species in this list.

FLORA OF CORAL REEFS.

The flora of the coral reefs is predominantly southern, of the 47 identified species and varieties found there (Table 2), 32 (68.1 per cent) being recorded for the Florida-West Indies region and 14 (29.8 per cent) being known from New England.

Comparing the three collections made on the principal reef, we find the species occurring as follows:

Date collected.	Species of algæ identified for coral reefs.				
	Total.	Recorded for—			
		New England.		Florida-West Indies.	
	Number.	*Number.*	*Per cent.*	*Number.*	*Per cent.*
May, 1907	21	9	42.8	18	85.7
August, 1914	25	6	24.0	15	60.0
July-August, 1915	22	10	45.4	20	90.9

This southern relationship is more striking when it is remembered that the visit to the reef in May was made at a time when Beaufort Harbor bore the spring flora, having 90.5 per cent of the species common to New England and only 33.3 per cent of the species common to the Florida-West Indies region. At this time several northern species which occur in this locality only in the spring were found on the reef. The small proportion of the species collected in August, 1914, which are common to other regions is due to the fact that four of these are new, while six are new to North America. If these species are excluded, the figures are New England 40 per cent, Florida-West Indies 100 per cent. Similarly, if two species new to North America collected in July and August, 1915, are excluded, the figures for this period are New England 50 per cent, Florida-West Indies 100 per cent. It could not be illustrated more forcibly that this flora is southern in its nature and that the species which are common to New England are those which are generally distributed and occur along the entire coast.

On all trips there were obtained from this reef species which were not found growing elsewhere in this region. In May, 1907, ten such species were observed, eight being distinctly southern, one being distinctly northern, and one being generally distributed. In August, 1914, there were observed, besides the ten species that are new or new to North America, eight species not found elsewhere in this region, seven being distinctly southern and one being generally distributed. In July and August, 1915, there were collected, besides the two species that are new to North America, nine species not found elsewhere in this region, seven being distinctly southern and two being generally distributed. It is thus seen that the flora that in this region is confined to the reefs is overwhelmingly southern in its relationship. Only four identified species were found in all three collections from the reef, while 14 were obtained in two collections, and 29 were found only once. This is probably an indication not so much of a seasonal distribution as of the abundance of the species occurring there and our ignorance of them. It is highly desirable that a thorough study of these reefs be made.

The southern character of the species occurring on this reef is further shown by the predominance of red algæ. The total numbers found in the different divisions are:

	Number.	Per cent.
Myxophyceæ	2	3.8
Chlorophyceæ	4	7.5
Phæophyceæ	11	20.8
Rhodophyceæ	36	67.9

FLORA OF BOGUE BEACH.

The flora which, in this locality, is found only on Bogue Beach (Table 3) is as pronouncedly southern as is that of the coral reef. Of the 18 identified species and varieties composing this list, 16 (88.8 per cent) are known from the Florida-West Indies region, while only four (22.2 per cent) are recorded for New England. This relationship is again shown by the predominance of red algæ. The total numbers found in the different divisions are:

	Number.	Per cent.
Myxophyceæ	1	4.6
Chlorophyceæ	3	13.6
Phæophyceæ	7	31.8
Rhodophyceæ	11	50.0

These facts support the suggestion previously made that most of these specimens have been washed in from the coral reefs offshore or from the reefs lying to the south of this locality, while some may have been brought by the Gulf Stream from the Florida-West Indies region.

CONDITIONS AT BEAUFORT, N. C.

HARBOR.

The principal factors affecting the growth and distribution of algæ are temperature, light, composition of the water, turbidity, movement of the water (including tidal range), and the nature of the habitat.

TEMPERATURE.

The temperature of the surface water at the laboratory wharf (on Pivers Island) has been taken at 5 p. m. almost daily during three periods, totaling almost four years. A full statement of these figures is given in Table 9. A summary of the records, stated in degrees centigrade, is as follows:

	Maximum.	Minimum.	Average.	Change of average since previous month.		Maximum.	Minimum.	Average.	Change of average since previous month.
	°C.	°C.	°C.	°C.		°C.	°C.	°C.	°C.
January	15.5	5.0	9.8	−1.3	July	31.0	25.0	27.9	+2.7
February	16.7	3.0	9.6	− .2	August	30.0	23.0	27.5	− .4
March	19.5	3.0	12.5	+2.9	September	28.9	17.8	24.8	−2.7
April	23.0	12.0	17.5	+5.0	October	25.0	14.0	19.2	−5.6
May	26.7	18.0	22.4	+4.9	November	20.0	7.8	13.9	−5.3
June	30.0	17.0	25.2	+2.8	December	17.0	6.0	11.1	−2.8

It will be seen that the extreme range of temperature recorded is 28°, from 3 to 31°. The lowest temperature and the lowest average occur in February, while the highest temperature and the highest average occur in July. In the fourth column there is given the change of the average since the previous month. It will be observed that the greatest increase of the average occurs from March to April (5°), while that from April to May is only 0.1° less (4.9°). The greatest decrease of the average occurs from September to October (5.6°), while that from October to November is nearly as great (5.3°). During the other eight months the average change is relatively small.

It is interesting to compare with these figures the surface temperatures (expressed in degrees centigrade) recorded for Woods Hole, Mass., by Sumner, Osburn, Cole, and Davis (1913) and those given for Naples by Berthold (1882), since the former locality has a temperate algal flora, while the latter locality has a subtropical one.

	Woods Hole, Mass.			Naples, Italy.
	Maximum.	Minimum.	Average.	
	°C.	°C.	°C.	°C.
January	4.16	−1.95	0.18	8–10
February	2.78	−1.95	−.56	
March	6.67	−1.38	2.04	
April	11.11	2.5	6.61	15–19
May	16.39	8.05	12.75	
June	20.56	14.16	16.94	20–25
July	23.33	17.22	20.43	
August	23.6	17.22	20.97	25–27
September	21.67	17.22	19.55	18–22
October	18.33	10.83	15.26	
November	12.78	3.6	9.03	....
December	8.6	−.28	3.01	....

At both of these places the highest temperature occurs in August and the lowest temperature in February. Woods Hole has a range of 25.55°, from −1.95 to 23.6°, while Naples has a range of 19°, from 8 to 27°. These figures indicate that Beaufort has a higher maximum and a lower minimum than Naples; but the record of Naples is less complete than that of Beaufort.

LIGHT.

While we have as yet no satisfactory measure of light, we can measure, in an approximate way, the relative effect under different conditions of the rays of light which affect photographic paper. This has been done in the present instance by means of the Clements photometer. This instrument uses a strip of solio paper, successive portions of which are exposed at will through a small slot, the slot being opened or closed as desired by means of a sliding cover. Standards for comparison are obtained by exposing portions of the paper to direct sunlight for different measured intervals of time. Another portion of the paper is exposed for a definite time in the situation whose light is to be tested. By comparison it is then determined which of the standards is darkened to the same extent as the paper exposed in the test situation. From the relative time of exposure of the test paper and this standard it is thus possible to estimate the relative amount of light in the test situation compared with full sunlight. For example, if paper exposed in a certain situation for 10 seconds is darkened to the same extent as a standard exposed to full sunlight for 5 seconds, we estimate that the light in this situation is 50 per cent as strong as full sunlight. It is, of course, necessary to make new standards for every series of tests, since the intensity of full sunlight will itself vary at different times and on different days.

Since the only photometer available to the author at that time was one intended for use in the air, this form was employed, being adapted as follows: All exposures were made with the photometer placed in a glass preserve jar of sufficient diameter to permit the photometer to lie flat on the bottom. The photometer was held in place by paper packed into the jar, care being taken that the slot for exposing the solio paper was not shaded by the packing. In a dim room the slot was opened, the photometer was placed in the jar and securely packed, and the jar was tightly wrapped in black cloth. This was then taken to the desired situation, the jar being held horizontally with the slot directly on top, the cloth was quickly removed for the desired number of seconds and then quickly replaced, and the jar was then brought back into the laboratory. All changes in the apparatus were made in a dim room at a considerable distance from any window. The standards were obtained in this way by exposing the photometer within the glass jar to direct sunlight on an upper, unshaded, southern porch.

For exposing the photometer below the surface of the water a shallow box, open at the top and of the proper size to hold the jar horizontally, was built, the sides of the box being just high enough to hold the jar in place and not shading the upper part of it. This box was then fastened to a handle marked with the desired distances. In a dim room the jar containing the opened photometer was placed horizontally in this box with the slot directly on top, and the box was tightly wrapped with black cloth. This was carried in a boat to the desired locality and held at arm's length below the water, the black cloth was then removed, and the jar immediately sunk to the desired depth and held at that level for a definite time. The jar was then quickly brought within reach and immediately covered with the black cloth, not more than a second being required for this manipulation. The apparatus was then carried to the laboratory, where all changes of the photometer were made in a dim room.

While the jar undoubtedly diminished the light reaching the photometer, this decrease would be the same in the standards and the tests. The effects of the light in these two cases may, therefore, be directly compared.

Two records, one at high and one at low tide, were obtained in this way in the channel in front of the laboratory wharf in July, 1907. In the first of these the standards were made from 1 : 15 p. m. to 2 p. m., July 17, and the measurements below the water were made from 1 : 15 p. m. to 4 p. m., July 18, high tide on this day occurring at 2 p. m. In some cases, where the color of the test did not exactly match that of any standard, the time of the standard having an effect equivalent to that of the test was obtained by interpolating between the two standards showing the colors nearest to that of the test. Standards were made by exposing to direct sunlight as described above for 60, 30, 25, 22, 20, 15, 10, 5, 3, 2, and 1 second. The results were as follows, the first column giving the depth below the surface at which the test was exposed, the second column giving the time of the exposure of the test, the third column giving the time of exposure of the standard having a color equivalent to that of the test, and the fourth column giving the calculated percentage intensity of the light at the respective depths compared with full sunlight:

Depth.	Length of exposure.	Equivalent standard.	Relative intensity.
	Seconds.	*Seconds.*	*Per cent.*
1 cm.	60	28.0	46.6
30 cm.	60	23.0	38.3
60 cm.	60	22.0	36.6
90 cm.	60	9.0	15.0
1.2 m.	60	5.0	8.3
1.5 m.	120	7.0	5.8
1.8 m.	180	4.5	2.5
2.1 m.	240	2.8	1.2
2.4 m.	300	3.0	1.0

The second record was made from 1 : 15 p. m. to 2 : 30 p. m., July 24, low tide on this day occurring at 2 : 15 p. m. The standards were made at 2 : 30 p. m. of the same day and were exposed for 60, 45, 30, 25, 20, 15, 10, 5, and 3 seconds. The results were as follows:

Depth.	Length of exposure.	Equivalent standard.	Relative intensity.
	Seconds.	*Seconds.*	*Per cent.*
1 cm.	60	40.0	66.6
30 cm.	60	17.5	29.1
60 cm.	60	2.8	4.6
90 cm.	120	3.0	2.5
1.2 m.	120	3.0	2.5
1.5 m.	120	3.0	2.5

While these two records differ considerably, they agree in their main points and indicate several interesting conclusions: (1) A considerable portion of the light (nearly one-half) did not penetrate below the surface, probably because of the reflection from the water and the suspended matter; (2) of the light which entered the water nearly one-half did not penetrate to a depth of 30 cm.; (3) at a slightly greater depth (1.2 m. at high tide, 60 cm. at low tide) the light was so reduced as to be almost lacking. These results are of great interest when considered in connection with the vertical distribution of the algæ. While some of the difference in the records may be due to errors in the determinations, a considerable part is probably due to the fact that one was taken at high and the other at low tide. The water at high tide is notably clearer than that at low tide, and the record taken at high tide shows a correspondingly greater light intensity.

These records, of course, show the effect of only the rays affecting solio paper, but it is these rays (toward the violet end of the spectrum) that are least absorbed by water. It is not known what proportion of the different rays penetrate water as turbid as that occurring here, or what is the intensity of the rays at the red end of the spectrum that reach the slight depths at which these measurements were made. There are evident errors in the methods used, but since the figures obtained could be, at best, only approximations, it did not seem worth while to give the time necessary to improving the records. The figures given refer only to the water in the channel in front of the laboratory wharf. Efforts to obtain records from other localities far removed from the laboratory were not successful, since the necessary changes of the photometer could not be made out of doors. These figures probably represent about an average of the conditions occurring through the greater part of the harbor. At certain places, especially near the inlet where the algæ are more abundant, the water is somewhat clearer.

SALT CONTENT OF WATER.

Determinations of the salt content of the water from five places in Beaufort Harbor were made by Wheeler (1910) in the summer of 1909 during the progress of the present study of the algæ. The water was obtained from (A) Beaufort Inlet; (B) the laboratory wharf; (C) Bogue Sound opposite Moorehead City; (D) between the eastern end of Beaufort and Bird Island Shoal; (E) Green Rock in Newport River near the entrance to Core Creek. The results, stated in parts per 1,000 grms. of water, were as follows:

	A.	B.	C.	D.	E.
$NaCl$	28.043	27.836	27.977	23.006	24.796
KCl	.842	.742	.751	.751	.702
$MgCl_2$	3.379	3.245	3.300	3.335	2.972
$MgSO_4$	2.417	2.328	2.320	2.372	2.062
$CaSO_4$	1.171	1.168	1.202	1.188	1.039
$CaCO_3$	.220	.214	.214	.215	.215
Total	36.072	35.533	35.764	35.867	31.786
Specific gravity at 28.7° C.	1.0227	1.0222	1.0226	1.0227	1.0193

As is shown, both the total salt content and the relative amounts of the different salts vary in different places and at different times, the total ranging, in these analyses, from 3.1786 per cent to 3.6072 per cent.

The density, of course, varies at different times, being largely determined by the amount of rain and the state of the tide. At times, after continued hard rains, the water in the harbor has, for days, the color of weak, muddy coffee, due to water coming from the inland juniper swamps. Daily salinometer readings have been made at 5 p. m. at the laboratory wharf (on Pivers Island) since June, 1913. A summary of these is as follows·

	Maximum.	Minimum.	Average.		Maximum.	Minimum.	Average.
1913.				1914.			
June	1.0228	1.0184	1.0209	January	1.0248	1.0186	1.0212
July	1.0238	1.0216	1.0228	February	1.022	1.010	1.0179
August	1.0226	1.020	1.021	March	1.0204	1.0112	1.0173
September	1.0204	1.0132	1.0168	April	1.0218	1.015	1.0183
October	1.0236	1.017	1.0199	May	1.0234	1.019	1.0212
November	1.024	1.0102	1.0209	June	1.0258	1.021	1.0234
December	1.0256	1.0192	1.0226	July	1.0246	1.022	1.023

It will be observed that the recorded density ranged from 1.010 to 1.0258. The general average, obtained by averaging the monthly averages, is 1.0205. In these figures no account is taken of the temperature, since in such salinometer records the errors of reading are almost certainly greater than the temperature corrections. For the same reason the maxima and minima are not accurate, but probably cover the range of variation. The averages, however, are probably fairly accurate, since they are obtained from a large number of readings where the errors probably balance each other. The general average, 1.0205, may, therefore, be taken as closely approximating the mean density of the water at the laboratory wharf. At other places in the harbor the density will, of course, be different from this. Since algæ grow throughout the harbor, some of them will be exposed to greater densities and some to lesser densities than those recorded here.

Several salinometer readings have been made by the author at other places in this region. While these have not the value of the daily records made at the laboratory wharf, they indicate the comparative density at other places. They are as follows:

Newport River near "Green Rock," low tide	1.016
North River near Lenoxville, low tide	1.0188
Pamlico Sound, Ocracoke, low tide	1.011
Coral reef off Beaufort	1.0242

TURBIDITY.

The water from the open ocean outside of the inlet contains a considerable amount of suspended matter, as is evident when this water is filtered, while the water within the harbor has still more fine, suspended matter and is, at times, very turbid. All rocks, shells, and posts under water are soon covered with a thick deposit, and at many places in the harbor the bottom is covered with mud up to a meter or more in depth. In the harbor and in Bogue Sound the amount of suspended matter seems to increase as we go farther from the inlet, while in the sound back of Shackleford Banks the water is decidedly clearer, owing to the strong current running in from the ocean at this place. Farther back in this sound the water is as turbid as in the harbor.

This turbidity not only reduces the light penetrating the water but itself affects the vertical distribution of algæ, since much of the suspended matter is deposited on all objects in the water. The older portions of the broader algæ (as Dictyota, Padina, the leaves of Sargassum) are more or less thickly covered by this mud settling from the water.

MOVEMENTS OF WATER.

The usual maximum range of tide (at the spring tides) is 0.97 m. (3.2 feet), the usual minimum range (at the neap tides) is 0.7 m. (2.3 feet), and the usual mean range is 0.82 m. (2.7 feet). The tides may, however, vary considerably from these figures, the actual height and range attained depending in part on the direction and strength of the wind. The greatest range observed by the author at the laboratory wharf is 1.31 m. (4.3 feet). The smallest range observed is 0.48 m. (1.6 feet). Under exceptional conditions the low tides are higher than the high tides recorded on other days in the same month, while at other times the tides are unusually low. Although there is not a very great difference in the height of water at high and low tides, there is a great difference in the amount of light reaching the algæ at these times. Except on Shackleford jetties, where the water is clearer, no algæ were found in the harbor below 1.4 m. below low water, and the majority were found within 75 cm. below low water. Most of the algæ have, therefore, about twice as much water over them at high tide as at low tide. Furthermore, during summer and autumn the greater number of algæ grow almost up to the surface of the water at low tide. For these parts of the plants the difference in the amount of water covering them at high and low tides is much greater than is indicated by the figures given above. For the species growing above low water the difference is, of course, still greater. Since light penetrates to such a slight depth in this water, the difference in the amount of light received by the plants at different stages of the tide must be very great. The difference is, however, partly neutralized for the algæ growing near the inlet and even as far back as the laboratory, since the water of the ocean is clearer than that of the harbor. This ocean water, entering the harbor at flood tide, pushes the more turbid water before it and mixes with it, so that, as was shown above, the water of the harbor is clearer at high than at ow tide.

Since the harbor is a comparatively small body of water and is well sheltered by land, the water is usually smooth throughout the greater part of its area. Near the inlet, however, there is considerable movement, although even here there are usually no waves. Even the slight movement that does occur here, however, probably affects the algæ growing on Fort Macon and Shackleford jetties by washing off the sediment that settles on them.

HABITATS.

The bottom throughout the harbor consists principally of sand, with some areas covered by mud or shells. (See map 2.) The mud and sand furnish no place of attachment for algæ. The shells furnish excellent places for attachment, but do not bear algæ, probably because of the turbidity of the water above them. Algæ are, however, found attached to single shells and other supports below low water along the shore and, sparingly, on the shoals.

The numerous wharf piles occurring here would seem to offer excellent habitats, but during the summer and autumn no algæ were ever found on them, while, on the contrary, during the spring they bore an abundant growth of algæ. The reason foı this difference is not apparent.

There remain, as possible algal habitats, the jetties at Fort Macon, at Shackleford and on the laboratory island, and the brick walls occurring along the town shore. These jetties bear the greater number, both of species and of individuals, of the algæ growing in the harbor, while the walls bear a limited number of species. Small species of algæ are found, too, in some abundance on the buoys that mark the channel into the harbor.

CORAL REEF.

The physical conditions existing on the coral reef offshore have already been described. Here it need be said only that the surface temperature at noon on May 15, 1907, was 21.11° C., the temperature at a depth of 25.5 m. was 19.44° C., and the density of the surface water (measured by a salinometer) was 1.0242. At this time the temperature of the surface water in the harbor varied, in different places and on different days, from 20.5° C. to 23° C., and the density varied from 1.0165 to 1.0212.

DISTRIBUTION OF ALGÆ AT BEAUFORT.

REGIONAL.

The regional distribution of algæ, their occurrence throughout the world, is, like that of other plants, determined largely by temperature. Whether a given algal species is able to exist in a given locality will depend absolutely on its ability to endure the maximum and minimum water temperatures occurring in that locality. It need not, however, be obliged to endure these extreme temperatures in its vegetative condition, but may exist for long periods by means of spores or fragments, resuming its vegetative state with the return of more favorable temperatures. Setchell (1915) has shown that the majority of the species of algæ occur in regions having a range of not more than 10° C., and that those occurring in regions having a greater range than this accommodate themselves to the general law by their seasonal distribution, etc.

Of the species which are able to exist in any given locality, some will thrive and will predominate, others will barely maintain a foothold, while others will appear and disappear at different times. The relative abundance of the different species occurring in any locality will be determined by the ability of these species to thrive under the conditions found there and to compete under these conditions with the other species growing in the region. To become abundant, a species must be able not only to endure the extreme conditions, but also to grow luxuriantly under the usual conditions. The factors most affecting the relative abundance of the species of marine algæ seem to be the temperature, density, and turbidity of the water, and the intensity of the light occurring, not on single days, but throughout the growing season.

As has been mentioned, the intermediate position of Beaufort makes its flora particularly interesting. Here *Codium tomentosum*, *Dictyota dichotoma*, *Padina vickersiæ*, and other strictly southern forms grow along with the more northern *Fucus vesiculosus* and *Polysiphonia harveyi*. As a rule, however, the northern and southern species do not grow together, the former occurring in the spring and the latter in summer.

Setchell (1915), in considering the effect of temperature on the distribution of algæ, distinguishes the following regions, based on the average temperature of the water during the summer expressed in degrees centigrade:

	°C.		°C.
Upper boreal	0 to 10	South subtropical	20 to 25
Lower boreal	10 to 15	South temperate	15 to 20
North temperate	15 to 20	Lower austral	10 to 15
North subtropical	20 to 25	Upper austral	0 to 10
Tropical	25 N. to 25 S.		

Since the average water temperature at Beaufort during the months from June to September is 26.35 °C., this classification would place the Beaufort area at the northern limit of the tropical region. It would seem, however, that the Beaufort flora should more properly be included in the subtropical region, and the limits given by Setchell should be modified.

SEASONAL.

As is shown in Table 1, the flora of spring and summer are very different. Of the 77 species and varieties growing in the harbor, only 15 (19.5 per cent) are found at both seasons, 11 of these being perennial and 4 having been found from April to October.

During the winter of 1908–9 monthly collections of all species observed were made for the author from the time of his departure from the laboratory, October 20, 1908, until his return, June 30, 1909. While more careful studies would probably alter the present data in some details, these collections and those made by the author in May, 1907, and April, 1908, give a fair picture of the seasonal distribution of the algæ in the harbor.

The species occurring there in the summer may be grouped as follows:

DOMINANT SPECIES.

Lyngbya confervoides.
Codium decorticatum.
Codium tomentosum.
Sargassum filipendula.
Dictyota dichotoma.
Padina vickersiæ.
Gracilaria confervoides.
Gracilaria multipartita.
Hypnea musciformis.
Chondria dasyphylla.
Dermatolithon pustulatum.

OCCURRENCE MORE LIMITED.

Ulva lactuca.
Ulva fasciata.
Ectocarpus mitchellæ.
Rosenvingea orientalis.
Fucus vesiculosus.
Erythrocladia recondita.
Erythrotrichia carnea.
Goniotrichum alsidii.
Acrochætium dufourii.
Acrochætium hoytii.
Acrochætium virgatulum.
Gelidium coerulescens.
Gelidium crinale.
Gymnogongrus griffithsiæ.
Actinococcus aggregatus.
Agardhiella tenera.
Eucheuma gelidium.
Champia parvula.
Lomentaria uncinata.
Chondria sedifolia.
Herposiphonia tenella.
Polysiphonia harveyi.
Polysiphonia denudata.
Ceramium tenuissimum.

The other species of the summer flora mentioned in Table 1 have been found only occasionally.

By the middle of October changes in the flora have become evident. Dictyota has become relatively scarce, and Padina is less abundant than formerly, the plants of both species being small and showing signs of degeneration; *Chondria dasyphylla* has almost disappeared; Hypnea is still abundant and shows little change except that there seems to be a greater preponderance of tetrasporic plants than formerly; Codium and *Gracilaria confervoides* are still present; Ectocarpus is abundant and conspicuous; large plants of Fucus are abundant and the fruits are well developed.

During November this change continues. Dictyota becomes still scarcer and finally disappears; Hypnea is reduced to small sterile plants, the condition in which it passes the winter (Pl. CI, fig. 2); and the first of the spring flora, *Petalonia fascia*, makes its appearance.

In December we find the last plants of Padina and the species growing on this, Erythrotrichia and Goniotrichum; *Gracilaria confervoides* has disappeared; *Codium tomentosum*, Champia, and *Chondria sedifolia* are still present; *Enteromorpha prolifera*, Agardhiella, and *Gracilaria multipartita* are more conspicuous; Petalonia grows to a large size; while occasional plants of Grinnellia and Dasya are found.

By January Champia and *Chondria sedifolia* have disappeared; *Ectocarpus confervoides* has replaced the summer species, *E. mitchellæ;* Grinnellia has become conspicuous, and small plants of Porphyra have appeared.

In February we find the last reduced plants of *Codium tomentosum* (*C. decorticatum* having disappeared earlier) and of *Chondria dasyphylla*. From this time the flora consists entirely of perennial and spring species. Porphyra has attained a large size; *Enteromorpha linza* has appeared; and *Enteromorpha prolifera*, *Ectocarpus confervoides*, Petalonia, Porphyra, Agardhiella, *Gracilaria multipartita*, and Grinnellia are the principal species composing the flora.

In March, the algæ are scarcer than at any other time during the year, but the perennial and spring species already mentioned are present without change, except that small plants of Leathesia have made their appearance.

During April the spring flora attains its greatest development. The dominant form throughout the harbor and along all the shores is *Ulva lactuca*, which occurs on all rocks and forms large masses lying free on the bottom. Closely rivalling this are *Enteromorpha prolifera* and Porphyra growing on all rocks and posts throughout the harbor. These three species are extremely abundant everywhere, but in limited areas they are surpassed by *Polysiphonia nigrescens* and *Ceramium strictum*. The species occurring here at this time may be grouped as follows:

ABUNDANT.

Lyngbya confervoides.
Enteromorpha linza.
Enteromorpha prolifera.
Ulva lactuca.
Ectocarpus confervoides.
Petalonia fascia.
Myrionema strangulans.
Leathesia difformis.
Fucus vesiculosus.
Porphyra leucosticta.
Acrochætium virgatulum.
Gelidium cœrulescens.
Agardhiella tenera.
Gracilaria multipartita.
Champia parvula.
Lomentaria uncinata.
Grinnellia americana.
Chondria tenuissima var. baileyana.
Polysiphonia nigrescens.
Dasya pedicellata.
Ceramium strictum.

OCCURRENCE LIMITED.

Enteromorpha flexuosa.
Enteromorpha intestinalis.
Chætomorpha melagonium f. rupincola.
Rhizoclonium riparium.
Cladophora flexuosa.
Bryopsis plumosa.
Ectocarpus siliculosus.
Stilophora rhizodes.
Sargassum filipendula.
Bangia fusco-purpurea.
Acrochætium corymbiferum.
Gelidium crinale.
Gymnogongrus griffithsiæ.
Hypnea musciformis.

Young plants of several species were observed at this time. Several specimens of Codium 3 to 12 mm. tall were found on shells in the clearer, deeper water north of the laboratory. Fucus showed, in addition to the large plants, many germlings 2 to 3 mm. tall. Small plants of *Chondria dasyphylla* also were observed.

Besides the germlings of Fucus, many large plants up to 14 cm. tall were present. These were entirely without fruit. Ulva, *Enteromorpha prolifera*, Lomentaria, and Champia grew more abundantly and to a larger size than in summer. Fruiting plants of Hypnea 1 to 6 cm. tall were observed, all of these being tetrasporic.

During May the spring species begin to disappear, some of the plants showing signs of disintegration. *Enteromorpha linza*, *E. prolifera*, *Chætomorpha melagonium f. rupincola*, Stilophora, Bangia, Porphyra, Dasya, *Polysiphonia nigrescens*, Grinnellia, and Ceramium are, however, still present. Hypnea has now attained its summer condition, the plants reaching a size of 22 cm.; *Chondria sedifolia* has appeared, and one small mass of *Rhodymenia palmetta* was found on Fort Macon jetty.

By June the spring flora has disappeared and the summer flora is established. The growth of the summer species at this time is very rapid. On May 14, 1909, the jetties at Fort Macon were carefully searched for Dictyota without revealing a trace of this species. On June 9, when the next collection was made, there were found numerous plants 20 to 29 cm. tall which had matured and liberated their sexual cells. The species present now include well-developed fruiting plants of Codium, Dictyota, Padina, Hypnea, *Chondria dasyphylla*, *C. sedifolia*, and Herposiphonia, and plants of Rhodymenia 6 cm. tall. None of the spring species was collected at this time.

All of the summer species are present before the first of July and maintain themselves until the following October or November.

From these facts we can picture the seasonal succession as follows: With the advent of colder temperature, the summer flora begins to disappear by the middle of October, the larger number of the species disappearing by November or December, others dropping out with each successive month, but some remaining until February. The first of the spring flora makes its appearance in November, other species appearing with each successive month, the flora, however, remaining relatively sparse during the winter, the smallest number of species being found in March. With the coming of warmer temperature, this flora becomes more abundant and reaches its greatest profusion in April, after which time it begins to dwindle and disappears by June. The first of the summer flora appears in April, others appear in May, and all are present before the last of June.

If the seasonal behavior of the algæ is compared with the recorded water temperature, it is observed that the disappearance of the summer flora in October and November is coincident with the greatest decrease in temperature; the appearance of the spring flora in November and the succeeding months follows this diminution; the time of greatest scarcity of algæ, in March, follows the lowest minimum temperature reached; the rapid increase of the spring flora to its maximum in April is coincident with the greatest increase in temperature, while its disappearance during May is coincident with the continued increase; and the appearance of the summer flora in April is coincident with this greatest increase and its profusion in June follows this great increase of temperature. It would scarcely be possible to find a more direct relation between temperature and the seasonal distribution of plants than is shown here. From this it seems evident that, while light probably has its effect, the seasonal distribution of algæ is determined to a very great extent by the temperature. More exact studies would probably show interesting relations between the temperature and the individual species occurring here.

The manner in which the summer species exist during the winter and the spring species exist during the summer at this place has not been determined. During the seven summers spent at the Beaufort laboratory, two small plants of Grinnellia and a few small plants of Dasya have been observed, but no other of the spring species has been found here after May, and none of the summer species has been found after February. Lewis (1914) has shown that, at Woods Hole, Mass., many of the summer species of red algæ occurring there (Dasya, Polysiphonia, and others) persist during the winter by means of the minute holdfasts of sporelings, the other portions of these sporelings and all of the older plants dying at the approach of cold weather. The plants arising from these holdfasts the following summer were mainly tetrasporic. Probably some such method carried the species over the unfavorable seasons at Beaufort. The rocks on which Dictyota and Padina grew the preceding summer and on which they occurred abundantly the following summer were carefully searched by the author under favorable conditions in April, 1908, without revealing a trace of these species. It is probable, however, that a microscopic examination would show these and other algæ present on the rocks below low water.

It is interesting to note that, although cystocarpic and tetrasporic plants of Hypnea are present in the summer in about equal numbers, a collection of 55 plants of this species taken at random in October showed 45 tetrasporic plants and 10 sexual ones, and all the fruiting plants observed in April were tetrasporic. Lewis (1914) has shown that the preponderance of tetrasporic plants in the early summer exhibited by the annual red algæ at Woods Hole is due to the fact that the two generations are produced alternately, the last crop of the summer being prevailingly sexual, and the carpospores borne by this crop producing the sporelings whose holdfasts persist through the winter. The perennial algæ at Woods Hole show no such discrepancy in the numbers of sexual and tetrasporic plants. In the present instance it seems that the tetrasporic plants of Hypnea, a perennial species, are themselves more resistant to cold than the sexual plants. Further studies are needed on this subject both here and in other regions.

The seasonal life cycle of Fucus may be summed up here for comparison with other regions. Young plants were observed in April along with large, old, sterile plants. The swollen receptacles become evident about June, but remain small and inconspicuous during July, becoming gradually larger and more conspicuous during August and September, and reaching full size about the latter part of October, the plants showing large, well-developed fruits from November to January or February. After this time all plants observed were sterile.

It is of interest to note that in May, 1907, when Beaufort Harbor bore almost entirely a spring flora, the coral reef offshore bore such strictly southern forms as Udotea, Dictyota, Zonaria, Nitophyllum, Chrysymenia, and others, along with the spring species of Dasya and Grinnellia, although at this time the water at the depth of this reef was at a lower temperature than that in the harbor. The explanation of this can not be given surely without further study, but certain differences between the harbor and the reef are evident. The greater clearness and higher salinity of the water over the reef probably play a part, but the chief factor probably is that the water at the depth of the reef, as may confidently be believed, does not fall to the low temperature found in the harbor in winter. This suggestion is supported by the species found on Bogue Beach during the winter from December, 1908, to March, 1909. Besides the species growing in the harbor, there were found during this time *Zonaria flava*, *Z. variegata*, *Nitophyllum medium*, *Polysiphonia havanensis*, and *Spermothamnion investiens*. The *Zonaria variegata* and *Polysiphonia havanensis* were found only once and may have been brought here by the Gulf Stream, but the other three species were not uncommon and may confidently be believed to have come from the coral reef offshore. *Codium tomentosum* was collected in December and April but not in the intervening months, while Dictyota was not found there until after its occurrence in the harbor in June. Data concerning the conditions and algæ occurring on the reef in winter would be of considerable interest, since it seems very probable that several species persist there throughout the year.

A comparison of the seasonal distribution of the Beaufort species which are found at Woods Hole and at Naples is given below, the numbers referring to the number of species and varieties common to Beaufort found in the other localities at the respective seasons:

Locality.	Beaufort summer flora.			Beaufort spring flora.				Beaufort perennial flora.		
	Winter.	Summer.	Perennial.	Winter.	Spring.	Summer.	Perennial.	Winter.	Summer.	Perennial.
Woods Hole	....	13	3	1	1	16	4	....	7	4
Naples	9	3	2	5	1	4	1	1	....	5

In this case many of the species recorded above for winter at Naples are found there from autumn through spring, and some of the species recorded for summer at Woods Hole are found there in spring and summer. In general, though, it will be seen that the relationships of the Beaufort flora are greater with that occurring at Woods Hole in summer and at Naples in winter.

The relations between the occurrence of any single species and the temperature are, however, frequently different in different localities. This is shown below where there is given the seasonal distribution of five species at Beaufort, Naples, and Woods Hole, with the range of the average temperature, in degrees centigrade, recorded in each locality during the time of occurrence of each species:

	Beaufort.	Naples.	Woods Hole.
Champia parvula	April to December, 17.5 to 27.9 to 11.1°.	Autumn to spring, 25 to 8 to 19°.	July to October, 20.43 to 20.97 to 15.26°.
Chondria dasyphylla	April to February, 17.5 to 27.9 to 9.6°.	Autumn to spring, 25 to 8 to 19°.	
Chondria tenuissima	April to June, 17.5 to 25.2°	Summer to autumn, 20 to 27 to 18°.	
Dasya pedicellata	December to June, 11.1 to 9.6 to 25.2°.	Spring to summer, 8 to 27°	
Polysiphonia denudata	July to October, 27.9 to 19.2°.	Perennial, 8 to 27°	

It will be observed that, while all of these species have the same seasonal distribution at Woods Hole, they occur at different seasons at Beaufort and at Naples, and, what is more important, they appear and disappear at different temperatures in each of the three localities. Further studies are needed to explain these facts.

Howe (1914) lists the following species found at and near Orient, N. Y., as having been gathered in Long Island Sound during the month February 7 to March 7: *Ulva lactuca*, *Chætomorpha linum*, *Sargassum filipendula*, *Agardhiella tenera*, *Champia parvula*, *Polysiphonia nigrescens*, *Ceramium rubrum*, *Dermatolithon pustulatum*. While further search would probably increase the number of perennial species listed for Beaufort, there is no evidence that Champia or Polysiphonia persists there during the winter.

VERTICAL.

The vertical distribution of the algæ at Beaufort is exceedingly limited, the total range of all species growing in the harbor being only about 2.2 m., from the usual high-tide line to about 1.4 m. below the usual lowest low tides. In fact, except at Shackleford jetties and the outermost jetty at Fort Macon, where the water is clearer and the algæ extend deeper, the great majority of algæ occur within a zone of 90 cm., from the level of the usual lowest low tide to 90 cm. below this. A careful search was made on the inner jetties at Fort Macon by means of oyster tongs and diving, a day being chosen when the water was about 15 cm. below the usual low tides. This showed algæ occurring abundantly to a depth of about 75 cm. below the usual level, then becoming scarcer and ceasing about 1.4 m. below this level, none being found as low as 1.7 m. In October, 1906, one of the jetties at Fort Macon, being undermined by the current, sank to a depth of about 6 m. When the rocks of this jetty were dredged up the following July they were entirely bare of algæ, although in the previous autumn they had borne numerous plants of Fucus, Sargassum, Dictyota, Hypnea, and other species occurring in this locality.

The lower limit of the algæ in this region is undoubtedly determined by the turbidity of the water and the consequent great diminution of the light penetrating to even moderate depths. It has been shown that the light reaching a depth of 90 cm. has an intensity of not more than 15 per cent of that of full sunlight, and that from 60 cm. to 1.2 m. there is a great decrease in the strength of the light. It will be observed that it is just at these depths that the algæ become scarcer and finally cease.

This turbidity, however, besides affecting the amount of light, probably itself plays a part in limiting the depth to which the algæ may grow, since these will receive sediment from all the water above them, and so will receive more deposits the greater the depth of the water covering them.

It is worthy of note that, while the algæ in the harbor grow to a depth of only 1.4 m., those on the coral reef grow to a depth of 25.5 m. This is undoubtedly due to the greater clearness of the water over this reef. All of the plants of Brongniartella, Dasya, Grinnellia, and Nitophyllum gathered from this reef were exceedingly pale in color, being much paler than plants of Dasya and Grinnellia growing in the harbor at the same time or than plants of Brongniartella and Nitophyllum observed in summer. This pale color may have been due to the weak light occurring at that depth or to a combination of this and other factors, but we do not yet know enough about the color of algæ to venture an explanation.

Except in the spring, the upper limit of the great majority of algæ in this region is determined by the height of the usual lowest low tides. *Lyngbya confervoides*, Hydrocoleum, several undeterminable species of Myxophyceæ, mats composed of minute plants of Enteromorpha, Ulva, Chætomorpha, and Cladophora, and plants of Fucus, Gelidium, Gymnogongrus, and Actinococcus occur between tide lines; but, except for these species and occasional plants growing in shaded or otherwise especially favorable locations, all algæ occurring here in summer are strictly limited to the zone below low tide. This is undoubtedly due to the intense insolation and heat to which the exposed plants are subjected, the air temperature sometimes rising to 36° C. At the time of the spring tides, when the range of tide is greatest, low tide occurs here about noon, so that all the algæ above low water are exposed to the sun during the hottest part of the day. Plants of Gracilaria, Hypnea, Chondria, Herposiphonia, and Nitophyllum have frequently been observed with a part or all of their thallus exposed by successive very low tides, and in every case they had been killed to the level of the water. Dictyota, Padina, and Rosenvingea seemed slightly more resistant, since plants that had been similarly exposed appeared uninjured in some cases, but at other times they too were killed to the water level. While a single very low tide, caused by the wind, may kill the exposed parts of the most tender species, it has little effect on the range of the algæ, but the successive very low tides, occurring at the time of the new and full moons, kill every plant growing above their level, with the exception of the species noted above, and therefore strictly determine the upper limit of all other species in this region.

The limits of the species growing between tide lines should be noted. Enteromorpha, Ulva, Chætomorpha, and Cladophora may be neglected in this connection, since these species occur here as mere fragments a few millimeters tall (in some being scarcely more than resistant holdfasts) and seem to merely endure the exposure between tide lines. Hydrocoleum has been collected only one time, intertwined with Gelidium. *Lyngbya confervoides* forms large mats covering all the walls and many of the jetties throughout the harbor from the usual low tide to the usual high-tide line. Fucus has about the same vertical range. Gelidium occurs in a zone about 60 cm. wide, from about 10 cm. above the usual low tide to about 12 cm. below the usual high-tide line. Gymnogongrus, with its parasitic Actinococcus, occurs from about 10 cm. below to about 30 cm. above the usual low tides. All of these species are enabled, by their structure, to endure prolonged exposure, and all of them except Gymnogongrus seem to require emersion, having their lower limits determined by the height of the usual low tides.

As the great majority of the species occurring here in summer are restricted by the heat to the zone below low tides, so those growing here in winter have their upper limit determined by the low-tide line on account of the cold, the air temperature sometimes falling as low as −9.5° C. No living algæ were reported above low water during the winter of 1908–9, all plants observed above this line appearing dead. While it is probable that more careful observation would show the presence of Lyngbya, Fucus, and possibly Gelidium and Gymnogongrus between the tide lines, nearly all the species undoubtedly have their upper limit determined, as in summer, by the height of the low tides.

In April and May many species occur above low water, but even at this time the majority are restricted to the zone below low tides. The vertical distribution of the species observed here at this time is as follows:

OCCURRING ONLY ABOVE LOW TIDE.

Lyngbya confervoides.
Leathesia difformis.
Porphyra leucosticta.
Gelidium coerulescens.
Gelidium crinale.

OCCURRING ONLY BELOW LOW TIDE.

Enteromorpha flexuosa.
Chætomorpha melagonium f. rupincola.
Cladophora flexuosa.
Bryopsis plumosa.
Ectocarpus confervoides.
Ectocarpus siliculosus.
Stilophora rhizodes.
Sargassum filipendula.
Agardhiella tenera.
Gracilaria multipartita.
Champia parvula.
Lomentaria uncinata.
Grinnellia americana.
Chondria dasyphylla.
Dasya pedicellata.
Polysiphonia nigrescens.
Ceramium strictum.

OCCURRING BOTH ABOVE AND BELOW LOW TIDE.

Enteromorpha linza.
Enteromorpha prolifera.
Ulva lactuca.
Petalonia fascia.
Fucus vesiculosus.
Bangia fusco-purpurea.
Gymnogongrus griffithsiæ.
Hypnea musciformis.
Chondria tenuissima.

It is worthy of note that Petalonia and Hypnea, which at other seasons are restricted to the zone below low water, now extend into the zone between the tide lines.

With the vertical distribution so limited, there is naturally little opportunity for the formation of distinct zones other than those occasioned by the growth of species above or below low water. While some species occur at slightly greater depths than others, the difference is so slight that it is scarcely capable of description.

HORIZONTAL.

The horizontal distribution is marked by a decrease in the number of both species and individuals as we go from the inlet in any direction, whether into the harbor, into Bogue Sound, or into Back Sound. The summer flora is the only one that has been studied in this connection. At this time the Fort Macon jetties bear a dense growth, Padina, Hypnea, and *Chondria dasyphylla* being the dominant forms, closely followed by Dictyota and Sargassum, bearing an abundance of Acrochætium and Herposiphonia, with Gymnogongrus, Codium, and *Gracilaria multipartita* occurring in considerable numbers and other species occasionally present. Between the jetties are numerous plants of Rosenvingea, *Chondria sedifolia*, and *Dermatolithon pustulatum* on eel grass (*Zostera marina*), while the innermost jetties bear an abundance of Fucus. *Lyngbya confervoides* and *Gelidium cœrulescens* cover the rocks and shells between tide lines on the jetties and along the shore.

On Shackleford jetties the same species are found except that *Chondria dasyphylla* is lacking, probably because this brittle species is unable to endure the strong tidal currents found there. Padina is the dominant species at this place, occurring with Sargassum in great fields on the rocks in this clear water to a depth of 1.4 m. *Gracilaria multipartita* is more abundant than on Fort Macon jetties and *G. confervoides* is present in large numbers. Rosenvingea, Fucus, and *Chondria sedifolia* were not observed here. Many plants of Padina growing in the most brightly lighted situations were slightly but decidedly calcified, while the majority of the plants here and all of this species observed elsewhere lacked this deposit.

Along the shore from Fort Macon jetties to Bogue Sound no algæ were found, probably because of the lack of places suitable for attachment, since the conditions here appear especially favorable for algal growth.

Of the 77 species and varieties recorded for the harbor, 65 have been found growing on the jetties and buoys near the inlet; the 12 species not found here being as follows:

Chroococcus turgidus?
Hydrocoleum lyngbyaceum.
Lyngbya lutea.
Oscillatoria nigro-viridis.
Ulva fasciata.
Ulva lactuca var. latissima.
Chætomorpha linum.
Chætomorpha brachygona.
Bryopsis plumosa.
Ectocarpus duchassaingianus.
Stilophora rhizodes.
Laurencia tuberculosa var. gemmifera.

The following 21 species have been found growing only in the vicinity of the inlet:

Enteromorpha flexuosa.
Enteromorpha intestinalis.
Chætomorpha melagonium f. rupincola.
Cladophora crystallina.[a]
Rhizoclonium riparium.
Leathesia difformis.
Rosenvingea orientalis.
Dictyopteris polypodioides.
Spatoglossum schroederi.
Acrochætium dufourii.
Acrochætium parvulum.[a]
Eucheuma gelidium.
Rhodymenia palmetta.
Nitophyllum medium.
Herposiphonia tenella.
Polysiphonia harveyi.
Polysiphonia denudata.[a]
Callithamnion polyspermum.
Ceramium tenuissimum?
Grateloupia filicina.
Amphiroa fragilissima.

In the vicinity of the laboratory (on Pivers Island) a fairly large flora occurs along the shores, especially around this island and along the town front, 43 species and varieties having been found growing here, as follows:

Chroococcus turgidus?
Hydrocoleum lyngbyaceum.
Lyngbya confervoides.
Lyngbya lutea.
Enteromorpha linza.
Enteromorpha prolifera.
Ulva fasciata.
Ulva lactuca var. latissima.
Ulva lactuca var. rigida.
Chætomorpha linum.
Bryopsis plumosa.
Codium decorticatum.
Codium tomentosum.
Ectocarpus confervoides.
Ectocarpus siliculosus.
Ectocarpus mitchellæ.
Petalonia fascia.
Myrionema strangulans.
Stilophora rhizodes.
Fucus vesiculosus.
Sargassum filipendula.
Dictyota dichotoma.
Padina vickersiæ.
Erythrotrichia carnea.
Porphyra leucosticta.
Acrochætium hoytii.
Acrochætium virgatulum.
Acrochætium corymbiferum.
Gelidium cœrulescens.
Gymnogongrus griffithsiæ.
Agardhiella tenera.
Gracilaria confervoides.
Gracilaria multipartita.
Hypnea musciformis.
Champia parvula.
Lomentaria uncinata.
Grinnellia americana.
Chondria dasyphylla.
Chondria tenuissima.
Dasya pedicellata.
Polysiphonia nigrescens.
Ceramium strictum.
Dermatolithon pustulatum.

These algæ have been found especially north and southwest of Pivers Island, on the laboratory jetties and along the town front, apparently because these localities had more places suitable for attachment.

Records for other localities in this region have been obtained only for the summer. During this season algæ are scarce in the harbor beyond the vicinity of the laboratory. Along the shores of the marshes north of Pivers Island and north of Morehead City there have been found only four species, as follows:

Ulva lactuca var. latissima.
Fucus vesiculosus.
Gracilaria confervoides.
Hypnea musciformis.

No algæ were found in the water extending into the marshes. This water is very muddy, is scarcely affected by ordinary tides, and frequently is very hot.

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[a] Found growing only on buoys.

In Newport River at "Green Rock," near the entrance to Core Creek, eight species were found as follows:

Ulva lactuca var. latissima.
Ectocarpus duchassaingianus.
Dictyota dichotoma.
Gelidium crinale.
Gracilaria multipartita.
Hypnea musciformis.
Laurencia tuberculosa var. gemmifera.
Polysiphonia sp.

In Bogue Sound, in the vicinity of Morehead City and on the north shore of Bogue Banks, the same conditions were found as were noted on the marshes north of Pivers Island, and a similar scarcity of algæ was observed. Owing to the difficulty of navigating here at low tide and the fact that conditions were so unfavorable for the growth of algæ, this sound was not explored further.

In North River near Lenoxville there were found six species, as follows:

Ulva lactuca var. latissima.
Ectocarpus mitchellæ.
Dictyota dichotoma.
Gracilaria confervoides.
Gracilaria multipartita.
Hypnea musciformis.

In Core Sound near Marshallberg, Lecklys Island, and Davis Island, there were found the following 10 species:

Ulva lactuca.
Dictyota dichotoma.
Erythrotrichia carnea.
Gelidium crinale.
Agardhiella tenera.
Hypnea musciformis.
Gracilaria confervoides.
Gracilaria multipartita.
Chondria sedifolia.
Dermatolithon pustulatum.

In Pamlico Sound at Ocracoke there were found the following 16 species:

Chroococcus turgidus?
Lyngbya semiplena.
Spirulina sp.
Enteromorpha prolifera.
Ulva lactuca.
Ulvella lens.
Gomontia polyrhiza.
Ectocarpus mitchellæ.
Acrochætium virgatulum.
Gelidium crinale.
Eucheuma gelidium.
Gracilaria multipartita.
Hypnea musciformis.
Chondria dasyphylla.
Spyridia filamentosa.
Dermatolithon pustulatum.

Although the records at places far from the laboratory were made from only one or two expeditions to these localities, they are believed to be fairly complete, since a thorough search was made at each place, and a second trip always verified the results obtained on a previous visit. The number of individuals at these places showed the same scarcity as the number of species.

It will be observed that *Ulva lactuca*, *Gracilaria confervoides*, *G. multipartita*, and *Hypnea musciformis* were most often present. No locality permitting the growth of any alga was found which did not bear at least three of these species.

The decrease in the algæ as we leave the inlet may, with considerable assurance, be ascribed to two factors, decreased density and increased turbidity. The former probably plays a part and may determine the limits of some of the species found only near the inlet, but the main factor limiting most of the species is undoubtedly the greatly increased turbidity. Even the parts of this region that have sandy and shelly bottoms have a thick covering of mud, and the water throughout the harbor and sounds is very turbid.

Many of the algæ growing in the localities noted above are covered with mud and have a pale, sickly appearance. Under such conditions it is not surprising that the number of species and individuals is small.

It is surprising, however, that the algæ were not more abundant in Pamlico Sound at Ocracoke. Here are several jetties and piles of shells that would seem to furnish excellent habitats for algæ. Ocracoke Inlet (leading directly to the open ocean) is only 2 km. away, and the water is not more turbid than around the laboratory in Beaufort Harbor; yet only 14 species were found there, the majority of the species that are dominant in Beaufort Harbor being entirely lacking. This scarcity may be due in part to the low density observed there, but further studies are needed to explain these facts.

The algæ collected in Newport River near "Green Rock" were, with the exception of Gelidium, mostly unattached. These seem to be plants that have been brought here by the tide and are continuing their existence floating near the bottom.

It is worthy of note that, with the exception of fragments of Enteromorpha, etc., on the sand breaks at Fort Macon and Shackleford, no algæ were ever observed during the summer growing on wood in Beaufort Harbor. Although there are numerous wharf, beacon, and railroad piles and two plank walls here with algæ attached to shells and stones near their bases, not a single specimen of algæ, not even Lyngbya, was ever found on these. In North River, Core Sound, and Pamlico Sound, on the contrary, there were found abundant Lyngbya and several plants of Enteromorpha, Ectocarpus, Dictyota, and Hypnea on the piles of wharves and beacons, and in the spring Enteromorpha, Porphyra, and other algæ grow abundantly on the wharf piles in Beaufort Harbor. The reason for this is not apparent, but it seems probable that it is caused by the crowding out of the algæ by sponges, barnacles, ascidians, and other animals which grow abundantly on these piles.

In no case have there been observed large numbers of animals and algæ growing together, the parts of both rocks and buoys which bear a conspicuous growth of algæ being comparatively free of animals and vice versa. Studies on this point would probably yield some interesting data.

OTHER LOCALITIES.

No extended studies have been made at any place other than Beaufort, but the observations made indicate that other localities, while differing considerably in detail, are affected by the same general factors as at Beaufort. With some exceptions the algæ are confined to the zone below low-tide line, they extend scarcely more than 90 cm. below low water, and they have to endure great turbidity. At no place, however, was there found anything approaching the number of species or of individuals observed at Beaufort. This seemed especially surprising in the case of Charleston, S. C., since a considerable number of species has been reported from this place by earlier collectors. Three days at different times during July and August were, however, spent in a careful search of this harbor, including James Island, Morris Island, Isle of Hope, and Isle of Palms, without revealing a large number of species or of individuals. While the records below were obtained from observations made on short visits to each place, they represent from one to three days' work in each locality and are believed to give a fair representation of the algæ present at these times. The species and varieties found are as follows:

BANKS CHANNEL, MASONBORO SOUND, WRIGHTSVILLE BEACH, N. C.

Ulva lactuca.
Codium decorticatum.
Codium tomentosum.
Ectocarpus sp.
Rosenvingea orientalis.
Dictyota dichotoma.
Gracilaria confervoides.
Gracilaria multipartita.
Hypnea musciformis.
Champia parvula.
Herposiphonia tenella.
Melobesia sp.

SOUTHPORT, N. C.

Lyngbya sp.
Enteromorpha prolifera.
Ulva lactuca.
Cladophora fascicularis.
Gracilaria multipartita.
Bostrychia rivularis.

GEORGETOWN, S. C.

Undetermined Myxophyceæ.
Enteromorpha prolifera.
Ulva lactuca.

PAWLEYS ISLAND, NEAR GEORGETOWN, S. C.

Enteromorpha prolifera.
Codium decorticatum.
Codium tomentosum.
Gelidium crinale.
Hypnea musciformis (2 cm. long).
Grinnellia americana (1 cm. long).
Dasya pedicellata (1 cm. long).
Herposiphonia tenella.
Polysiphonia denudata? (2 cm. long).

CHARLESTON, S. C.

Chætomorpha linum.
Gelidium coerulescens.
Agardhiella tenera?
Gracilaria confervoides.
Gracilaria multipartita.
Grateloupia gibbesii.

PORT ROYAL, S. C.

Enteromorpha iinza.
Enteromorpha prolifera.
Gracilaria multipartita var. angustissima.
Gracilaria confervoides.
Lomentaria uncinata.
Polysiphonia harveyi.
Polysiphonia denudata.

TYBEE, GA.

No algæ except undetermined Myxophyceæ on oyster shells.

METHODS FOR COLLECTING AND PRESERVING ALGÆ.

Many excellent specimens of algæ may be gathered from the beach, where they are thrown by the tides and waves, but satisfactory collections can be obtained only from the places where they are growing. Except in deep water, where the tide makes no appreciable difference, all collections should, of course, be made at low tide. The algæ are procured in three ways: Those growing between tide lines or near the surface are collected by hand; at a greater depth they may be gathered by long hooks, rakes, or tongs; while those growing at great depths are obtained by dredging. These three methods differ greatly in their relative values. Those stations which may be reached by hand can be thoroughly searched in a relatively short time, while those which are at greater depths require repeated collections extending through several years before we can be reasonably sure of having a fair representation of the species growing there. Collins has aptly compared the collections of algæ obtained by dredging with those of other plants which might be gathered from a large field on a dark night by means of an aeroplane and a long rake. In clear, still water the use of a glass-bottom boat or bucket, enabling one to see the algæ which are growing at considerable depths, may be used to advantage, but in this region one can not see farther below the surface with a glass-bottom boat than without it.

The large, coarse algæ, which are more abundant farther north and are represented here only by Fucus, need no special care after being collected, but most other algæ are easily injured. These may be carried for a short time in an ordinary collecting can or other vessel that will protect them from the sun and keep them moist, but they should be placed in sea water as soon as possible, preferably as soon as they are collected. In any case, a large-mouthed bottle should be carried to hold the smaller, more delicate species that may be found.

Farther north, where the air temperature is much higher than that of the water, most algæ die soon after being gathered, since they can not endure the change of temperature to which they are exposed; but in this region algæ may be kept for days in jars of sea water, provided that they are clean and that very few specimens are placed in each jar.

For preservation, the algæ should be dried. Large, coarse species, as Fucus, may be dried between blotters under pressure or may even be spread out and allowed to dry in the air. In the latter case, however, it is difficult to make them lie flat when it is desired to mount them on paper. All other forms should be mounted on paper as soon as possible, any thick, unglazed paper being suitable for this. With the larger, more rigid, specimens, one may simply shake off the water and spread these out on the paper. The more delicate specimens should be floated in sea water, the paper slipped under them, and the algæ arranged on the paper, needles being used if necessary. The hand is then placed under the center of the paper, and this, bearing the specimen, is carefully removed from the water. The alga is then arranged on the paper in the position that shows it to greatest advantage, needles and water dropped carefully upon it from a pipette being most useful for this operation.

Having mounted the specimens, one should then dry them under moderate pressure between plant driers or blotters, first laying some thin, white cloth over the algæ to keep them from sticking to the driers. A very good plant press may be made from boards weighted with stones. The driers should be changed at least twice a day and should be thoroughly dry when used. Specimens should be kept in the press until all moisture is removed from them.

Microscopic forms should be mounted in such a way that they may be examined with the microscope, thin sheets of mica being good for this purpose. The brittle corallines are always difficult objects to handle. Some of them may be pressed flat while living and may then be fastened to paper by gummed tape. They should be kept in folders to preserve any fragments that may be broken off. Some minute algæ adhering closely to rocks can best be preserved by breaking off pieces of the rock on which they are growing. Any specimens that do not adhere to paper may be fastened on with gummed tape.

The above directions will serve as suggestions for beginners and will hold for the majority of species, while the experience and ingenuity of the collector will enable him to devise ways to handle the more difficult forms that may be found.

ECONOMIC USES OF ALGÆ.

From a utilitarian standpoint algæ are of value in four ways: (1) As food; (2) as a source of glue, gelatin, and agar-agar for jellies, culture media, and other purposes; (3) as a source of iodine, potassium, and other chemical substances; (4) as a fertilizer which may be applied directly to the soil.

Since the substances contained in algæ have little food value, their use as food must correspond to the use of green vegetables, such as spinach or lettuce, or of condiments. In this way they are used in large quantities and with great relish in other countries. Of the genera in this region, Enteromorpha, Ulva, Codium, Dictyota, Porphyra, Gracilaria, Hypnea, Chondria, and probably many others might be thus employed. Considerable information regarding the use of algæ for food and in other ways is given by Smith (1905), by Miss Reed (1907), and by Howe (1917).

It is well known that the "Irish moss," *Chondrus crispus*, of more northern shores may be used for the preparation of jelly and blancmange. Only one species, *Gracilaria confervoides*, has been tested here for this purpose, but from that species a very good jelly was obtained. The procedure is as follows: The plants of Gracilaria are cleaned, washed, bleached, and dried in the sun for several days, being repeatedly washed during this time with fresh water. The algæ is then heated in water for one or two hours to extract the gelatinizing substances and is strained. The resulting strained jelly is sweetened and flavored to taste, set in a cool place to harden, and is served with cream. Blancmange may be made in the same way, using milk instead of water. Other gelatinous algæ, as Gelidium, Agardhiella, and *Gracilaria multipartita*, probably could be used for this purpose in the place of *G. confervoides*.

No species of algæ occurs in this region in sufficient quantity to be of commercial value for the manufacture of gelatin or agar-agar, but on other portions of our coast gelatinous algæ occur in large numbers and probably could be utilized in this way. In the past agar-agar has been made principally in Germany from algæ obtained from Japan. It is probable that experiments would show that this could be made from algæ growing on our coasts, provided the proper algæ could be found in sufficient quantities.

The algæ used as sources of iodine and potassium are the rockweeds and kelps. Of these only Fucus occurs in this region, and this is not in sufficient quantities to be of value.

In the north the rockweeds and kelps furnish a valuable source of fertilizer, which, after rotting, may be applied directly to the soil. These algæ, with the exception of Fucus, are not found here, and no other species grows in the harbor in sufficient quantity to warrant its being gathered for this purpose. After hard storms, however, algæ are found on Bogue Beach in enormous masses, composed principally of Zonaria and Sargassum. If these were gathered and allowed to rot in the open, where they would be washed free of salt water, they would probably be found an excellent fertilizer and would supply the organic matter needed by a very sandy soil.

PART II. SYSTEMATIC ACCOUNT OF THE ALGÆ.

IDENTIFICATION OF ALGÆ.

The main groups of algæ are usually easily distinguished, since they differ markedly in their structure and usually in their color.

The Myxophyceæ, or "blue-green algæ," consist of cells of relatively simple structure living singly or joined into loose colonies or united into filaments; they are usually gelatinous and, as their common name implies, usually have a dark, blue-green color. By these characters they are easily distinguished from all others.

The Chlorophyceæ, or "green algæ," consist of single cells, filaments, sheets, or more complex structures. If the structures are complex, they are not composed of closely packed cells, but of interwoven filaments which are easily seen when teased apart and examined with slight magnification. They are light or dark yellow green, the color of grass and leaves, and are not likely to be mistaken for any other group. Some of them are encrusted with lime.

The Phæophyceæ, or "brown algæ," are easily distinguished by their brown color, which may, however, have the shade of walnut or mahogany, or may tend toward olive green. They consist of filaments or of more or less complex cellular structures.

The Rhodophyceæ, or "red algæ," consist of filaments, sheets, irregular aggregations, or complex cellular structures of various forms. They sometimes furnish difficulties to beginners, since their color and form are extremely various, the former ranging from red or pink to dark purple on the one side and to a decided green on the other. If green, they may be distinguished by the fact that their structure, at least in part, shows a close cellular arrangement and does not consist entirely of interwoven filaments. A still surer character for fertile specimens, once it has been recognized, is the fruit borne by all but the simplest members of this group. This is the cystocarp, which consists essentially of a mass of spores radiating from a common center and surrounded by a sterile jacket of some sort. This may be immersed and relatively inconspicuous but frequently forms more or less conspicuous conical projections above the surface. Even when immersed it is usually plainly seen as it is borne in a swollen part of the frond.

While, however, the main divisions are easily distinguished, the smaller groups often furnish considerable difficulty. Once they have been seen, the genera of the blue-green, green, and brown algæ may usually be easily recognized, or may even be identified with certainty from illustrations, but it is often difficult to place a given specimen of red algæ in its proper genus or even in its proper family or order. In many cases species of all the divisions are distinguished with great difficulty and only after careful study and comparison of many specimens. It can not be hoped, therefore, that the following descriptions will enable a determination to be made in every case. It should be borne in mind by a beginner that, while many forms may be recognized at a glance, others require much study and can be determined only when all the distinguishing characters are present. Frequently forms must be left undetermined because the material is not sufficient. One should, therefore, collect an abundance of every unknown species. In all cases it is desirable to compare the specimens with some that have been correctly determined, since one good specimen will convey a better idea of the species than it is possible to get from pages of description. Those using the keys given here should remember that these are made only for the species that have been found in this region, and if used in other regions or if other species should be found here, they may lead the beginner astray.

CLASSIFICATION AND DESCRIPTION OF SPECIES.

KEY TO DIVISIONS.

a. Thallus composed of single cells or of rather short filaments; multiplication purely vegetative, either by simple cell division or by means of hormogonia or gonidia; color usually blue-green .... I. MYXOPHYCEÆ (p. 407).

aa. Thallus composed of single cells, or filamentous, or forming tubes or sheets or complex structures of various shapes composed of closely interwoven filaments; multiplication asexual or sexual—asexual by fragmentation or by motile zoospores or by akinetes, sexual by similar or dissimilar motile or nonmotile gametes; color usually grass-green .... II. CHLOROPHYCEÆ (p. 417).

aaa. Thallus filamentous or forming complex structures of various shapes; multiplication asexual or sexual—asexual by motile biciliate zoospores or by aplanospores or by certain portions of the thallus, sexual by similar or dissimilar motile or nonmotile gametes, in some genera by distinct eggs and sperms; color usually brown, sometimes shading to yellowish or to olivaceous green .... III. PHÆOPHYCEÆ (p. 435).

aaaa. Thallus filamentous or forming sheets or complex structures of various shapes; multiplication asexual or sexual—asexual usually by nonmotile spores usually produced four in a sporangium, sexual by nonmotile male gametes (spermatia) and nonmotile female gametes remaining inclosed within special organs (carpogonia), usually with the association of special cells (auxiliary cells), a fruit of a special kind (cystocarp) usually being formed as the result of fertilization; color usually some shade of red, purple, or pink, sometimes green or blackish .... IV. RHODOPHYCEÆ (p. 462).

Division I. MYXOPHYCEÆ (Wallroth) Stizenberger.[a]

Myxophykea Wallroth, 1833, p. 4.
Chlorospermeæ, in part, Harvey, 1858, p. 1.
Myxophyceæ, Stizenberger, in Rabenhorst, 1860, p. 18.
Cryptophyceæ, Thuret, in Le Jolis, 1863, p. 13.
Cyanophyceæ, Sachs, 1874, p. 248.
Schizophyceæ, Cohn, 1879, p. 279.
Cryptophyceæ, Farlow, 1882, p. 26.
Myxophyceæ, Forti, in De Toni, 1907, p. 1.
Myxophyceæ, Tilden, 1910, p. 1.

BLUE-GREEN ALGÆ, FISSION ALGÆ.

Algæ typically blue-green, possessing within their cells endochrome composed of chlorophyll and a characteristic blue pigment; pigments of other colors sometimes present; endochrome diffuse, rarely gathered in large, sharply defined bodies. Thallus variable in form and size, unicellular or multicellular, sometimes having a peculiar motion; plants usually in gelatinous masses, sometimes solitary among other algæ. Multiplication purely vegetative; either by simple cell division in one, two, or three planes; or by means of hormogonia (multicellular fragments of the thallus, at first motile, afterwards coming to rest); or by means of nonmotile gonidia formed within gonidangia; or by means of resting gonidia (formed from ordinary cells). Algæ living for the most part in fresh or salt water, sometimes aerial, more rarely endophytic; the individual cells and filaments microscopic in size; sometimes brown, violet, gold, or reddish.

About 1,500 species described, representatives occurring in all parts of the world, at extreme variations of temperature.

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[a] This group is often treated as a class under the division Schizophyta, which then includes the Myxophyceæ, or as they are sometimes called, the Schizophyceæ (the blue-green algæ), and the Schizomycetes (the bacteria).

This division, well represented in most regions, here forms a very small part of the marine flora, only 10 genera and 10 species having been obtained in quantities sufficient for determination.

KEY TO ORDERS.

Plants unicellular, single, or associated in families, which are usually surrounded by a gelatinous integument, not filamentous .... 1. COCCOGONEÆ (p. 408).
Plants multicellular (except Spirulina), filamentous. .... 2. HORMOGONEÆ (p. 409).

Order 1. **Coccogoneæ** (Thuret) Kirchner.

Plants unicellular, single, or associated in families or colonies which are usually surrounded by a copious gelatinous integument, rarely forming filaments; multiplication occurs commonly by the vegetative division of cells, rarely by the formation of four or more nonmotile gonidia arising from the division of the contents of a cell (gonidangium).

Family 1. CHROOCOCCACEÆ Nægeli.

Cells solitary or associated in families, showing no difference between basal and apical regions; multiplication usually by simple division of the cells.

Unicellular algæ, entirely uniform, occurring singly or more often in clusters which are conspicuous even to the naked eye, the cells grouped without order in a common sheath. Cells spherical, oval or elongate, sometimes fusiform, cuneate, or squarish. Extremely minute bodies containing diffuse blue, æruginous, or even purple, olive, brown, or yellow coloring matter occur in the cells. The cell wall is sometimes thin and delicate, sometimes thick, often surrounded by a structureless, gelatinous sheath which holds the cells together for many generations and forms families variable in number and appearance of the cells. Divisions usually in three planes forming families irregularly grouped, but also in two planes forming layers of sheetlike families, or even in one plane, forming families at first linear, then by mechanical action irregularly grouped and contorted. Propagation in the Chroococcaceæ living singly does not occur except by the vegetative division of the cells, in those species living gregariously it occurs either by the separation of a single cell or by the splitting up of an old family into several families. Spores provided with a thickened resistant wall have been observed occasionally in species of Glœocapsa; these arise from the vegetative cells and are formed by the repeated division of the contents or by the dissolution of the membrane.

About 300 species, mostly in fresh water, less often in salt water or in damp places or aerial, throughout the world.

Genus Chroococcus Nægeli.

Chroococcus Nægeli, 1849, p. 45.

Cells globose, or by mutual pressure more or less angular, each surrounded by a more or less definite sheath; solitary or associated in families composed of two or four, rarely more, individuals, but not held together in definite colonies by a common gelatinous sheath; cell wall thin or wide, homogeneous or lamellose, colorless or colored; cell contents homogeneous or granular, æruginous or blue-green, sometimes yellowish or orange or violet; multiplication by successive division of the cells alternately in three planes; free floating or forming a gelatinous or crustlike mass in damp places.

Forty-eight species, mostly in fresh water or in damp places, some in salt water, some in the tissues of other plants; throughout the world.

Chroococcus turgidus (Kuetzing) Nægeli.

Protococcus turgidus, Kuetzing, 1845, tom. 1, pl. 6, f. 1.
Chroococcus turgidus, Nægeli, 1849, p. 46.
Chroococcus turgidus, Farlow, 1882, p. 27.
Chroococcus turgidus, Wolle, 1887, p. 334, pl. 210, f. 40–41.
Chroococcus turgidus, Forti, in De Toni, 1907, p. 11.
Chroococcus turgidus, Tilden, 1910, p. 5, pl. 1, f. 3.
P. B.-A. Nos. 751, 2202.

Cells spherical, oblong-elliptical, or more or less angular from mutual pressure, single or associated in families of two, four, rarely eight, 13 to 25, rarely 40 mic. in diameter; sheaths thick, usually lamellose, hyaline, cell wall thin, cell contents pale blue-green, homogeneous, later becoming brownish and granular.

On moist rocks and occasionally in salt marshes throughout the world.

Very abundant, with *Microcoleus chthonoplastes* and *Plectonema battersii* on ocean beach at Ocracoke, N. C. (?); covering many square meters just beyond high-tide line, August, 1907, on shells in Pamlico Sound; fairly abundant on rocks and shells and on *Gelidium cærulescens*, Fort Macon and Duncan breakwater, Beaufort, N. C. (?), forming small masses not visible to the naked eye.

The material from Core Sound and from Beaufort seemed to belong to this species but occurred so scatteringly that it could not be obtained in sufficient quantity for a positive determination.

Order 2. **Hormogoneæ** (Thuret) Kirchner.

Nostochineæ, Farlow, 1882, p. 29.

Plants multicellular, rarely unicellular (Spirulina), filamentous, attached to a substratum or free floating; filaments simple or branched, usually consisting of one or more rows of cells within a sheath; multiplication occurs by means of hormogonia or resting gonidia.

KEY TO FAMILIES.

a. Filaments attenuated at apex, usually tapering to a hair; attached at base. .4. RIVULARIACEÆ (p. 416).
aa. Filaments never tapering to a hairlike apex...*b*.
b. Filaments simple or branched, if branched having several or many trichomes within each sheath, heterocysts lacking....................................1. OSCILLATORIACEÆ (p. 409).
bb. Filaments simple, heterocysts present.......................................2. NOSTOCACEÆ (p. 414).
bbb. Filaments (or trichomes) regularly branched, having only one trichome within the sheath, heterocysts present..3. SCYTONEMACEÆ (p. 415).

Family 1. OSCILLATORIACEÆ (Gray) Kirchner.

Trichomes simple, composed of similar vegetative cells, rarely unicellular, usually surrounded by a sheath; filaments simple or rather sparsely branched, containing one or more trichomes; filaments and trichomes rarely occurring scattered, usually forming scum, membranes, mats, etc.; propagation by hormogonia; no heterocysts.

Usually blue-green, less often violet or brownish, rarely red. Cells usually short-cylindrical or disk-shaped; less often barrel-shaped, in Spirulina long cylindrical and spirally twisted. Apical cell rounded or wedge-shaped, sometimes calyptrate, sometimes tapering slightly. Filaments usually straight, often curved or spirally twisted at the apices, in certain genera spirally twisted throughout the entire length. Often several trichomes occur within a single more or less coarse sheath, forming a single filament. Sheaths sometimes delicate and inconspicuous, sometimes coarse, even exceeding the diameter of the trichome; walls of sheaths sometimes very firm, sometimes gelatinous, so that they adhere together very easily. Propagation occurs by hormogonia—longer or shorter fragments of trichomes, breaking out the sheaths and moving of themselves by circumnutation in the water, then, the movement ceasing, sheaths are formed and cell division commences. In the genera without sheaths—e. g., Oscillatoria, Spirulina—the movements persist throughout their life.

The Oscillatoriaceæ inhabit principally moist, aerated places; many live in water containing decaying organic matter; some are incrusted with calcium carbonate; some thrive in temperatures as high as 85° C.

About 550 species throughout the world.

The members of this family are usually easily distinguished in that they do not taper to long hairs at the apices, they lack heterocysts, and in the majority of cases are unbranched. The only species found in this region that is likely to be wrongly identified as belonging to this family is *Plectonema battersii*, one of the Scytonemaceæ. This species lacks hairlike apices and heterocysts and might easily be taken for one of the branching Oscillatoriaceæ. From these it can be easily distinguished by the fact that it has only one trichome within a sheath, while both Hydrocoleum and Microcoleus have several or many trichomes within each sheath.

KEY TO GENERA.

a. Sheaths absent .... *b*.
  b. Trichomes straight or nearly so, multicellular .... 1. Oscillatoria (p. 410).
  bb. Trichomes forming a regular spiral, unicellular .... 2. Spirulina (p. 411).
aa. Sheaths present .... *c*.
  c. Filaments consisting of one trichome within each sheath, simple .... *d*.
    d. Sheaths swollen, gelatinous, filaments more or less agglutinated .... 3. Phormidium (p. 411).
    dd. Sheaths not swollen, firm, filaments free or forming a tangled mat, not agglutinated .... 4. Lyngbya (p. 411).
  cc. Filaments consisting of several trichomes within a single sheath, simple or branched .... *e*.
    e. Filaments consisting of few trichomes within a single sheath, trichomes often loosely aggregated .... 5. Hydrocoleum (p. 413).
    ee. Filaments consisting of numerous trichomes within a single sheath; trichomes densely aggregated, often twisted into ropelike bundles .... 6. Microcoleus (p. 413).

Genus 1. **Oscillatoria** Vaucher, ex Gomont.

Oscillatoria, Vaucher, 1803, p. 165.
Oscillaria, Farlow, 1882, p. 32.
Oscillatoria, Gomont, 1892, tome 16, p. 198.

Trichomes cylindrical, free, usually motile, without a sheath or rarely inclosed in a very thin, fragile, mucous sheath, sometimes constricted at the joints, not moniliform, often attenuated at the apices, straight or curved or more or less regularly corkscrew-shaped in some species, but not constantly spiral; outer wall of apical cell thickened in some species, forming a calyptra.

About 100 species in fresh or salt water, sometimes in hot springs or on moist earth, throughout the world.

Oscillatoria nigro-viridis Thwaites, ex Gomont.

Oscillatoria nigro-viridis, Thwaites, in Harvey, 1851, pl. 251a.
Oscillaria limosa var. *chalybea*, Farlow, 1882 p. 33.
Oscillatoria nigro-viridis, Gomont, 1892, tome 16, p. 217, pl. 6, f. 20.
Oscillatoria nigro-viridis, Forti, in De Toni, 1907, p. 161.
Oscillatoria nigro-viridis, Tilden, 1910, p. 69.
P. B.-A. No. 1056.

Plant mass very dark olive green; trichomes moderately long, rather straight, fragile, constricted at joints, arcuate toward the extremities, tapering and obtuse at the apices, 7 to 11 mic. in diameter, cells 3 to 5 mic. long; apical cell somewhat capitate with convex and slightly thickened outer wall; transverse walls granulated, cell contents pale green or olive.

Maine to West Indies; Washington; Europe; Australia.

Several large masses floating in harbor, August, 1909, in sparse tufts on marine grasses, shoals west of laboratory, and near "Green Rock," Beaufort, N. C.

A few other specimens belonging to this genus have been found at Beaufort in small quantities on shells or marine plants, or growing directly on sandy shoals between tide lines, but none has been obtained in sufficient quantity for a specific determination.

Genus 2. **Spirulina** Turpin, ex Gomont.

Spirulina, Turpin, 1827, tome 50, p. 309.
Spirulina, Gomont, 1892, tome 16, p. 249.

Trichomes unicellular, thin, cylindrical, without a sheath, forming a regular, rather loose or close spiral, having a characteristic spiral movement; apex not tapering, cell contents homogeneous or slightly granular.

Twenty-one species in fresh or salt water, gathered into a continuous layer or scattered among other algæ, in America, Europe, Africa, and Australia.

A few filaments of an undetermined species of Spirulina were found on shells in Pamlico Sound at Ocracoke, N. C.

Genus 3. **Phormidium** Kuetzing, ex Gomont.

Phormidium, Kuetzing, 1843, p. 190.
Phormidium, Gomont, 1892, tome 16, p. 156.

Filaments showing evident sheaths, unbranched, agglutinate, usually forming a felt-like mat with free ends torn and ragged, attached at the base or rarely floating; sheaths thin, transparent, mucous, adhering to each other, partly or entirely diffluent; trichomes constricted at the joints in some species, sometimes even becoming moniliform, straight or curved but never regularly spiral, often tapering toward the apices, outer wall of apical cell thickened, in some species, to form a calyptra.

About 70 species, usually terrestrial or in fresh water, some species marine.

Many filaments of an alga apparently belonging to this genus, but insufficient for specific determination, were found on the hydroids inhabited by *Acrochætium infestans* growing on *Dictyota dichotoma* dredged from the coral reef offshore, August, 1914. These filaments had trichomes 0.75 to 1.5 mic. in diameter with cells 0.75 to 3.0 (mostly 1 to 2) diameters long, and were closely adherent to the stalks and rhizomes of the hydroids.

Genus 4. **Lyngbya** Agardh, ex Gomont.

Lyngbya, Agardh, 1824, p. XXV.
Lyngbya, Gomont, 1892, tome 16, p. 116.

Filaments possessing evident sheaths, free, unbranched, free floating, or forming a densely intricate floccose or expanded mass; sheaths firm, of variable thickness, sometimes lamellose, colorless or rarely yellow brown; trichomes sometimes constricted at the joints, obtuse or slightly tapering at the apices, outer wall of apical cell sometimes thickened, forming a calyptra.

Seventy-five species in fresh or salt water throughout the world.

KEY TO SPECIES.

Trichomes 9 to 25 mic. in diameter, cells 2 to 4 mic. long; sheaths up to 5 mic. thick, colorless, later becoming lamellose; apex not tapering, no calyptra, transverse walls usually granulated........1. *L. confervoides* (p. 412).

Trichomes 5 to 12 mic. in diameter, cells 2 to 3 mic. long; sheaths up to 3 mic. thick, colorless, lamellose with age; apex slightly tapering, furnished with calyptra, transverse walls frequently granulated........2. *L. semiplena* (p. 412).

Trichomes 2.5 to 6 mic. in diameter, cells 1.5 to 5.5 mic. long; sheaths thin, colorless, later becoming thick and lamellose; apex not tapering, furnished with calyptra, transverse walls usually not distinct........3. *L. lutea* (p. 413).

1. **Lyngbya confervoides** Agardh, ex Gomont.

Lyngbya confervoides, Agardh, 1824, p. 73.
Lyngbya confervoides, Harvey, 1858, p. 103, pl. 47c.
Lyngbya nigrescens, Harvey, 1858, p. 102, pl. 47d.
Lyngbya luteo-fusca, Farlow, 1882, p. 35 (excluding synonyms).
Lyngbya confervoides, Gomont, 1892, tome 16, p. 136, pl. 3, f. 5-6.
Lyngbya confervoides, Forti, in De Toni, 1907, p. 271.
Lyngbya confervoides, Tilden, 1910, p. 119, pl. 5, f. 39.
A. A. B. Ex. No. 48 (L. luteo-fusca).
P. B.-A. Nos. 255, 1106.

Plant mass about 5 cm. in height, forming extensive mats or an intricate ragged mass, fasciculate, mucous; dull yellowish or dark green, sometimes violet when dry; filaments tangled, long, straight, somewhat rigid, ascending from a decumbent base; sheaths up to 5 mic. thick, colorless, later becoming lamellose and roughened on the surface; trichomes not attenuated at the apices, not constricted at the joints, 9 to 25 mic. in diameter, cells 2 to 4 mic. long, apical cell rotund, no calyptra; transverse walls usually granulated; cell contents olive or blue-green.

Maine to Florida; Nebraska; West Indies; warm and temperate waters everywhere.

Very abundant on rocks and shells along town front, especially on Duncan breakwater, very abundant on rocks of Fort Macon jetties, and less abundant on rocks of Shackleford jetty, Beaufort, N. C. Forms the uppermost zone of algæ occurring up to the median high-tide line, sometimes mixed with minute specimens of Cladophora, Chætomorpha, and Enteromorpha, sometimes forming pure growths over large areas. April to October, probably throughout the year. This is the only species belonging to the Myxophyceæ that has been found at Beaufort in sufficient quantity to be conspicuous.

2. **Lyngbya semiplena** (Agardh) J. Agardh, ex Gomont.

Calothrix semiplena, Agardh, 1827, p. 634.
Lyngbya semiplena, J. Agardh, 1842, p. 11.
Lyngbya semiplena, Gomont, 1892, tome 16, p. 138, pl. 3, f. 7-11.
Lyngbya semiplena, Forti, in De Toni, 1907, p. 273.
Lyngbya semiplena, Tilden, 1910, p. 118, pl. 5, f. 38.
P. B.-A. Nos. 5, 1059, 1452.

Plant mass rarely beyond 3 cm. in height, forming extensive mats, mucous; usually dull yellowish or dark green, becoming dark violet when dry; filaments ascending from a decumbent tangled base, soft, flexuous; sheaths up to 3 mic. thick, colorless, somewhat mucous, lamellose with age; trichomes slightly attenuated at the apices, not constricted at the joints, 5 to 12 mic. in diameter, cells 2 to 3 mic. long, apical cell bearing a depressed conical or rotund calyptra, transverse walls frequently granulated.

Maine to North Carolina, probably farther; Nebraska; Washington; California; Mexico; West Indies; Hawaii; Atlantic and Mediterranean shores of Europe.

Very abundant, forming extensive mats almost covering posts of wharf and beacon between tide lines, mixed with other Myxophyceæ, Ocracoke, N. C.

3. **Lyngbya lutea** (Agardh) Gomont, ex Gomont.

Oscillatoria lutea, Agardh, 1824, p. 68.
Lyngbya tenerrima, Farlow, 1882, p. 35.
Lyngbya juliana, Wolle, 1887, p. 301, pl. 202, f. 20–21.
Lyngbya lutea, Gomont, 1890, p. 354.
Lyngbya lutea, Gomont, 1892, tome 16, p. 141, pl. 3, f. 12–13.
Lyngbya lutea, Forti, in De Toni, 1907, p. 275.
Lyngbya lutea, Tilden, 1910, p. 114, pl. 5, f. 30–31.
P. B.-A. No. 854.

Plant mass somewhat gelatinous, leathery, yellowish brown, or olive, often becoming dark violet when dry; filaments coiled, flexible, densely entangled; sheaths colorless, smooth, at first thin, later becoming thick (up to 3 mic.) and lamellose; trichomes not constricted at the joints, not tapering at the apices, 2.5 to 6 mic. in diameter, cells 1.5 to 5.5 mic. long, apical cell showing a rotund calyptra, transverse walls usually not distinct, cell contents granular, olive green.

Maine to Florida and Alabama; West Indies; Europe; Dalmatia; northern Africa.

In sparse tufts on marine grasses, shoals west of laboratory, Beaufort, N. C., August, 1907.

Genus 5. **Hydrocoleum** Kuetzing, ex Gomont.

Hydrocoleum, Kuetzing, 1843, p. 196.
Hydrocoleum, Gomont, 1892, tome 15, p. 332.
Hydrocoleus, Forti, in De Toni, 1907, p. 315.
Hydrocoleus, Tilden, 1910, p. 134.

Filaments possessing evident sheaths, forming heaped or indefinite masses, or layers not massed, giving a tangled mat, very rarely hardened with lime; sheaths always colorless, cylindrical, somewhat lamellose, more or less mucous or somewhat formless and entirely dissolving on the older filaments; trichomes few within the sheath, often loosely aggregated, more or less false branching, apex of trichome straight, more or less attenuated, outer membrane of apical cell thickened into a calyptra, cells shorter than the diameter of the trichome, in some species very short.

Twenty species in fresh and salt water throughout the world, mostly marine.

Hydrocoleum lyngbyaceum Kuetzing, ex Gomont.

Hydrocoleum lyngbyaceum, Kuetzing, 1849, p. 259.
Lyngbya arenarium, Wolle, 1887, p. 299, pl. 201, f. 27–29.
Hydrocoleum lyngbyaceum, Gomont, 1892, tome 15, p. 337, pl. 12, f. 8–10.
Hydrocoleus lyngbyaceus, Forti, in De Toni, 1907, p. 317.
Hydrocoleus lyngbyaceus, Tilden, 1910, p. 135, pl. 5, f. 58.
P. B.-A. Nos. 204, 205.

Dark green mats or a broadly expanded gelatinous layer; filaments adnate, unbranched at base, branched in upper portions, false branches numerous, somewhat appressed; sheaths wide, mucous, containing one or more trichomes, roughened in outline, acuminate or often open at apex, sometimes entirely dissolved and agglutinated; trichomes 8 to 16 mic. in diameter, not constricted at the joints, numerous at the base of the filaments, spirally twisted and entangled, solitary in the branches, cells 2.5 to 4.5 mic. long, apex of trichome attenuated, truncate, transverse walls granulated.

Massachusetts to Florida; Bermuda; West Indies; warm and temperate waters generally.

Fairly abundant on *Gelidium cærulescens*, Duncan breakwater, Beaufort, N. C., forming small tufts 1 to 2 cm. long tangled in the upper branches of the host.

Genus 6. **Microcoleus** Desmazieres, ex Gomont.

Microcoleus, Desmazieres, 1823, p. 7.
Microcoleus, Gomont, 1892, tome 15, p. 350.

Filaments possessing evident sheaths, simple or vaguely branched; sheaths colorless, more or less regularly cylindrical, not lamellose, in some species finally dissolving; trichomes many within a sheath, closely crowded, often twisted into ropelike bundles in well-developed filaments, apex of trichome straight, attenuated, apical cell acute, rarely obtusely conical, capitate in one species.

Thirteen species in fresh or salt water or on the ground, sometimes growing among other algæ, throughout the world.

Microcoleus chthonoplastes (Mertens) Thuret, ex Gomont.

Conferva chthonoplastes, Mertens, in Flora Danica, 1818, Fasc. 27, p. 8, pl. 1485.
Microcoleus chthonoplastes, Thuret, 1875, p. 378.
Microcoleus chthonoplastes, Farlow, 1882, p. 33, pl. 2, f. 3.
Microcoleus gracilis, Wolle, 1887, p. 306, pl. 203, f. 10–11.
Microcoleus anguiformis, Wolle, 1887, p. 306.
Microcoleus chthonoplastes, Gomont, 1892, tome 15, p. 353, pl. 14, f. 5–8.
Microcoleus chthonoplastes, Forti, in De Toni, 1907, p. 371.
Microcoleus chthonoplastes, Tilden, 1910, p. 155, pl. 6, f. 28.
P. B.-A. Nos. 153, 906, 1854.

Filaments forming a dull or dark green, ragged, spreading, compact, stratified mass, made up of layers of different colors, or growing sparsely among other algæ; tortuous, not often branched; sheaths cylindrical, unequally roughened on the surface, with apex usually open, sometimes entirely dissolving; trichomes blue-green, short, nearly straight, many within the sheath, usually densely aggregated into bundles, rarely twisted into cords, constricted at the joints, 2.5 to 6 mic. in diameter, cells 3.6 to 10 mic. long, apex of trichome attenuated, apical cell not capitate, acutely conical, transverse walls not granulated.

Canada to North Carolina; Texas; Ohio; Illinois; Dakota; Washington; West Indies; warm and temperate waters generally.

Very abundant with *Chroococcus turgidus* and *Plectonema battersii* on ocean beach at Ocracoke, N. C., covering many square meters just beyond high-tide line, August, 1907.

Family 2. NOSTOCACEÆ (Agardh) Kirchner.

Nostochaceæ, Forti, in De Toni, 1907, p. 383.

Trichomes simple, consisting of similar vegetative cells, not differentiated into basal and apical regions, not tapering to hairs at the apices, usually provided with heterocysts, naked or inclosed in a mucous, gelatinous, or membranaceous sheath; multiplication by gonidia and hormogonia.

Usually æruginous—green. Trichomes straight or twisted or curved, of equal diameter throughout or tapering very slightly toward the apices, heterocysts terminal or intercalary. Sheaths usually gelatinous, often dissolving into an inclosing jelly, often adhering to each other, more rarely membranaceous and cylindrical, colorless or yellowish or olivaceous, containing one or more trichomes.

The Nostocaceæ live on moist earth, among mosses, etc., often in quiet fresh water, sometimes in rapid streams, sometimes in salt or brackish water, a few being endophytic.

About 220 species throughout the world.

Genus **Microchæte** Thuret, ex Bornet and Flahault.

Microchæte, Thuret, 1875, p. 378 (7).
Microchæte, Bornet and Flahault, 1887, p. 83.

Filaments possessing evident sheaths, unbranched, erect, attached at the base, solitary or forming small cushionlike tufts; trichomes single within the sheath, hetorocysts basal or intercalary, gonidia formed near the base.

Eleven species, all minute, in fresh or salt water, widely distributed.

Microchæte nana Howe and Hoyt. Pl. CXVII, figs. 12–17.

Microchæte nana, Howe and Hoyt, 1916, p. 105, pl. 12, figs. 12–17.

Plants inconspicuous, almost microscopic, forming loose, scattered clusters over the surface of the host; filaments mostly 0.1 to 0.2 mm. long, curved near base or near middle, usually more or less horizontal toward the base and erect toward the apex, sometimes almost prostrate throughout or almost erect throughout, tapering very slightly toward the apices; sheath very thin, delicate, scarely visible; trichomes light olivaceous (?), 5.0 to 8.3 mic. in diameter, slightly constricted at the septa toward apex, scarcely so below, cells 1 to 3 (mostly 1.5–2) times as broad as long, the apical ones broadly dome-shaped or almost hemispheric; heterocysts basal, usually single, rarely double, subspherical or ovoid, 5.0 to 6.6 mic. in diameter, or sometimes 8.3 mic. long, gonidia unknown.

Endemic.

Few patches of scattered filaments on *Dictyota dichotoma* dredged from the coral reef offshore from Beaufort, N. C., August, 1914.

This species will not be mistaken for any other occurring in this region. It has been found only the one time noted.

Family 3. SCYTONEMACEÆ (Kuetzing) Rabenhorst.

Scytonemataceæ, Kirchner, in Engler and Prantl, 1900, p. 76.

Trichomes composed of a single row of cells, one or more included within a sheath, not ending in a hair at the apex; filaments branched, false branches formed by the perforation of the sheath by the trichome which thereupon issues as one or two long, flexuous branches, each developing a sheath of its own; sheaths homogeneous and colorless, or lamellose and yellowish or brownish, firm, tubular, sometimes incrusted with lime; heterocysts and gonidia variously distributed, sometimes lacking; multiplication by means of vegetative division, hormogonia, and gonidia.

Filaments usually forming tufted masses, sometimes matted or ragged layers. Vegetative cells cylindrical or barrel-shaped, rarely spherical, apex hemispherical or semi-ellipsoid, cell contents blue-green or sometimes violet or rose-red. Filaments nearly uniformly thick at all points, and always with false branching; false branches always occur in connection with the heterocysts, when these are present, going out either immediately below a heterocyst or midway between two of these, the latter method giving a pair of branches. Heterocysts present except in Plectonema, subspherical, oval, or cylindrical, at the bases of the branches or intercalary in the filaments, single or several adjoining, always attached to the inner wall of the sheath.

About 150 species, mostly aerial or on moist earth or in fresh water, throughout the world.

Genus **Plectonema** Thuret, ex Gomont.

Plectonema, Thuret, 1875, p. 375.
Plectonema, Gomont, 1892, tome 16, p. 96.

Filaments free or forming feltlike masses, branched, false branches solitary or in pairs; sheaths firm, colorless or rarely yellowish orange; trichomes frequently constricted at the joints, apex of trichomes straight, very rarely attenuated, calyptra none, heterocysts and gonidia none.

Twenty-one species, mostly in fresh water, rarely on soil, few in salt water, America, Europe, Asia.

Plectonema battersii Gomont.

Plectonema battersii, Gomont, 1899, p. 36.
Plectonema battersii, Forti, in De Toni, 1907, p. 495.
Plectonema battersii, Tilden, 1910, p. 211.
P. B.-A. No. 1060.

Plant mass blackish or brownish green; filaments elongate, flexuous, abundantly and repeatedly branched, false branches usually in pairs, more slender than the main filaments; sheaths colorless, somewhat thick in the main filaments; trichomes 2 to 3.5 mic. in diameter, constricted at joints, with somewhat attenuated apices, apical cell rotund, cells up to four times shorter than diameter. cell contents homogeneous, pale blue-green.

Maine; Massachusetts; England; Norway.

Very abundant with *Chroococcus turgidus* and *Microcoleus chthonoplastes* on ocean beach at Ocracoke, N. C., covering many square meters just beyond high-tide line, August, 1907.

This is the most southern station reported for this species.

Family 4. RIVULARIACEÆ (Meneghini) Kirchner.

Filaments tapering from base to apex, terminating above in a colorless hair, simple or branched, associated in brushlike or gelatinous layers, rarely solitary; false branches due to development of a new trichome from a cell of the main trichome, usually occurring immediately under an intercalary heterocyst, rarely by the perforation of the sheath between two heterocysts by the trichome, either separating immediately and forming a new sheath, or remaining for some time within the original sheath; heterocysts usually present, usually basal, occasionally intercalary; multiplication by vegetative division and hormogonia, sometimes by gonidia.

The apical cells always seem nearly empty and are usually colorless; the basal cells show blue-green, violet, red, or brownish cell contents. Sheaths cylindrical, gelatinous or membranaceous, homogeneous or stratose, colorless, yellowish or brownish. The sheaths are often split by apical elongation into superposed lamina; often the inner sheaths, becoming dissolved, pass out from the apex; often incrusted with lime. Hormogonia are situated at the apices of the filaments and branches and, the apical hairs being shed, pass out from the apices. To this is due the fact that the older filaments sometimes lack the apical hairs. In some genera Chroococcus-like masses are formed at the base from the vegetative cells and later grow into filaments.

About 170 species, in fresh and salt water, throughout the world.

Genus **Dichothrix** Zanardini, ex Bornet and Flahault.

Dichothrix, Zanardini, 1858, p. 297.
Dichothrix, Bornet and Flahault, 1886, p. 373.

Plant mass cæspitose, penicillate, or pulvinate, filaments more or less dichotomously branched; sheaths cylindrical, trichomes often several (2 to 6) inclosed in a common sheath, heterocysts sometimes basal, sometimes intercalary, in one species not present, no gonidia.

Thirteen species in fresh or salt water, America, Europe, Africa.

Dichothrix penicillata Zanardini, ex Bornet and Flahault.

Dichothrix penicillata, Zanardini, 1858, p. 297, pl. 14, f. 3.
Dichothrix penicillata, Bornet and Flahault, 1886, p. 379.
Dichothrix penicillata, Forti, in De Toni, 1907, p. 644.
Dichothrix penicillata, Tilden, 1910, p. 280.
P. B.-A. Nos. 62, 1112.

Plant mass cæspitose, fastigiate-penicillate, scattered or clustered, dark green; filaments short, flexuous, 2 mm. long, 25 to 35 mic. diameter (in ultimate branches); sheaths thick, gelatinous, soft, uniform, colorless; trichomes 15 mic. broad; cells shorter than diameter, cell contents olive, heterocysts oblong, solitary.

Florida; Mexico; West Indies; Guadeloupe; Red Sea.

Covering a considerable portion of one piece of *Sargassum natans*, Bogue Beach, Beaufort, N. C., June 29, 1907; one small tuft (8 to 10 filaments) on one piece of *Chondria littoralis*, Bogue Beach, September 19, 1906. (?)

The last-mentioned tuft seemed to belong to this species, but contained too few filaments for a positive determination. This is the most northern station reported for this species.

In addition to the species described above, members of the Myxophyceæ were observed in more or less abundance at Marshallburg, N. C.; Southport, N. C.; Georgetown, S. C.; and Tybee, Ga.; but the material from these places proved indeterminable or, for various reasons, has not been determined.

Division II. CHLOROPHYCEÆ (Kuetzing, in part) Wittrock.

Chlorospermeæ, in part, Harvey, 1858.
Zoosporeæ, in part, Farlow, 1882
Oosporeæ, in part, Farlow, 1882.

Green Algæ.

Algæ chlorophyll green (rarely red, yellowish, or brownish, sometimes grayish from deposits of lime), containing pure chlorophyll in their cells (rarely mixed with other pigments); chlorophyll confined to definitely limited bodies, the chloroplasts. Thallus consisting of one or more cells, simple or branched, filiform or of various shapes, filamentous, membranaceous, or tubular. Multiplication asexual or sexual: asexual (propagation) by the fragmentation of the entire plant or of some part, or by noncopulating motile cells (zoogonidia, zoospores, swarm spores), or by resting cells (akinetes, aplanospores); sexual (reproduction) by at least eventually nonmotile zygotes (zygospores, oospores) formed by the copulation or conjugation of gametes free of membranes; gametes similar (isogametes), or different in form, size, etc., that is, male and female (heterogametes), motile or nonmotile.

The members of this group live mostly in water, either salt or fresh, while some occur on moist soil and some are endophytic. The akinetes and aplanospores are formed from vegetative cells. Zoospores are formed either from ordinary vegetative cells or from special cells, zoosporangia; they are pear-shaped, bear two or four, less often one or many, cilia on their anterior, pointed, colorless end, and often have a red eyespot and contractile vacuole; they come to rest after a longer or shorter time, develop a membrane, and usually develop immediately into new plants. Zygotes are formed in one of three ways: (1) By the copulation of two motile gametes, exactly alike or differing slightly in size; (2) by the fertilization of a large nonmotile female gamete (egg) by a small motile male gamete (sperm); (3) by the copulation or conjugation of two nonmotile gametes similar in appearance. The similar gametes are formed from ordinary cells; eggs and sperms are developed in special organs, oogonia and antheridia. The zygote, in some cases, develops immediately into a new plant, but in the majority of forms, after a period of rest, develops swarm spores, which, after swimming about, come to rest and grow into new plants.

There is no other group of algæ about which there is so much difference of opinion concerning the classification. The name Chlorophyceæ is here used in a broad sense, including the Heterokontæ, Stephanokontæ, Conjugatæ, etc., of other authors. There seems to be need for a name covering this assemblage of forms which seem to show more or less close relationship to each other. For these it has seemed desirable to retain the old, inclusive name, at least until some uniformity of opinion can be reached regarding their division. In this scheme the divisions of other authors (Conjugatæ, Heterokontæ, etc.) would be subdivisions under Chlorophyceæ.

Nearly 3,000 species; throughout the world.

KEY TO ORDERS

a. Frond usually of relatively large size, multinucleate, without division into cells.......
....3. SIPHONALES (p. 430).
aa. Frond divided into cells...*b*.
b. Cells uninucleate, chromatophore usually single, disk or net-shaped......1. ULOTRICHALES (p. 418).
bb. Cells multinucleate, chromatophore net-shaped, or of numerous small disks in a cell
....2. SIPHONOCLADIALES (p. 423).

Order 1. **Ulotrichales.**

Confervoideæ, in part, De Toni, 1889.
Confervoideæ, in part, Wille, in Engler and Prantl, 1897.

Simple or branched filaments, sometimes membranes, rarely in few-celled families; cells uninucleate, rarely multinucleate; chromatophore usually single, band, disk, net, or star shaped, generally with one or more pyrenoids. Marine and fresh water.

KEY TO FAMILIES.

Frond membranaceous, either flat or forming a tube...............................1. ULVACEÆ (p. 418).
Frond filamentous, branching, or a few-celled family; usually with hairs...2. CHÆTOPHORACEÆ (p. 422).

Family 1. ULVACEÆ (Lamouroux) Rabenhorst.

Membranaceous, plane, or tubular fronds; cells uninucleate, with disk-shaped chromatophores and one pyrenoid; asexual propagation by four-ciliate zoospores (sometimes biciliate?); sexual reproduction by similar biciliate gametes.

Near the base of the frond the cells may send down rhizoidal prolongations to the substratum, often uniting to form a thickened stipe; otherwise than this there is no specialization of cells. Zoospores or gametes may be formed in any cell of the frond except the lowest cells. The zygospore formed by the fusion of two gametes, after a short period of motility with four cilia, settles down, loses its cilia, surrounds itself by a membrane, and develops immediately into a new plant, forming a filament or small sack which soon changes into the characteristic form of the frond.

About 100 species, mostly marine, rarely in fresh water, mostly in the littoral zone throughout the world from Arctic to Antarctic regions.

KEY TO GENERA.

Frond tubular or flattened; simple or branched...............................1. Enteromorpha (p. 418).
Frond flat, often forming extensive sheets......................................2. Ulva (p. 420).

Genus 1. **Enteromorpha Link.**

Enteromorpha, Link, 1820, p. 5.
Ulva enteromorpha, Farlow, 1882, p. 43.

Frond originating in a single series of cells, which by repeated division form a tubular frond (sometimes flattened), the membrane of which consists of a single layer of cells; in some of the simpler species the tubular stage is not reached, and the frond in the adult state consists of two or a few series of cells, united without any interior space; simple or branched; cells often arranged in longitudinal series. All the cells of the frond, except the lowest, capable of producing zoospores or gametes, which are discharged through an opening in the cell wall.

Frond always attached at first, later often free floating. The genus is connected with Ulva by *E. linza*, in which the tube is compressed and the membranes united in the middle part.

Thirty species, usually in salt or brackish water, occasionally in fresh water, throughout the world.

The specific distinctions are founded chiefly on the manner of branching and on the size and arrangement of the cells and are often difficult of determination.

KEY TO SPECIES.

a. Frond flat, the membranes free at the margins, but united between.............4. *E. linza* (p. 420).
aa. Frond tubular...*b*.
  b. Cells not arranged in longitudinal series except in the very youngest parts.............
    ....3. *E. intestinalis* (p. 420).
  bb. Cells more or less in longitudinal series, usually in the greater part of the frond..............*c*.
    c. Fronds simple, inflated, and flexuous.................................2. *E. flexuosa* (p. 419).
    cc. Fronds regularly branched...1. *E. prolifera* (p. 419).

1. **Enteromorpha prolifera** (Flora Danica) J. Agardh.

Ulva prolifera, Flora Danica, vol. 5, fasc. 14, p. 7, pl. 763, fig. 1, 1832.
Enteromorpha prolifera, J. Agardh, 1882, p. 129, pl. 4, figs. 103–104.
Enteromorpha prolifera, De Toni, 1889, p. 122.
Enteromorpha prolifera, Collins, 1909, p. 202.
P. B.-A. Nos. 470, 610, 913.

Frond up to several meters long and 2 cm. in diameter, tubular or compressed, with more or less abundant branches which are usually simple, but sometimes also proliferous; branches varying much in length and diameter; cells 10 to 12 mic., in the younger parts always arranged in longitudinal series, which become less distinct in the older parts; membrane 15 to 18 mic. thick, not much exceeding the dimensions of the cells in cross section.

Greenland to West Indies; Alaska to California; Europe.

Beaufort, N. C.: Abundant throughout winter 1908–1909; very abundant May, 1907, and April, 1908, on rocks, shells, and piers throughout harbor and at Fort Macon and Shackleford, extending from about 10 cm. below low water to high-water line; very abundant at water line on sea buoy and channel buoy at entrance to Beaufort Harbor, July, 1909; abundant on rocks and sand breaks at Shackleford and Fort Macon between tide lines throughout summer (?). Cape Lookout beach, very abundant on old wreck about 20 m. from water at low tide, August, 1906. Pamlico Sound, Ocracoke, N. C., fairly abundant on posts of beacon between tide lines (?). Southport, N. C., very abundant on wall and shore, August, 1909. Georgetown, S. C., very abundant on jetty and shells on beach. Pawleys Island, near Georgetown, S. C., abundant on shells in bay near inlet. Port Royal, S. C., fairly abundant on buoy at water line.

This seems to be the only species of Enteromorpha occurring in this region throughout the year. Specimens collected in December are 3 to 4 cm. long, densely matted with many upright, filiform or club-shaped branches; in April and May this species is, next to *Ulva lactuca*, the most abundant in the harbor; the specimens at this time are 3 to 45 cm. long; in summer, material apparently belonging to this species is found as small, stunted tufts, 1 to 2 cm. long, on rocks and sand breaks near the inlet, this condition continuing as late as October or November. With the exception of these stunted representatives and of specimens occasionally growing on buoys, etc., this species has not been found here during the summer or autumn.

In habit this species is very variable, from slender, slightly branched forms, only a few centimeters long, to rich and repeatedly branched fronds; delicate or coarse; branches sometimes long and slender, sometimes short and very densely set, sometimes long and short intermingled quite without order. It also occurs in fresh water and about salt springs.

2. **Enteromorpha flexuosa** (Wulfen) J. Agardh.

Conferva flexuosa, Wulfen, in Roth, 1800, p. 188.
Enteromorpha flexuosa, J. Agardh, 1882, p. 126.
Enteromorpha flexuosa, De Toni, 1889, p. 121.
Enteromorpha flexuosa, Collins, 1909, p. 203.
P. B.-A. Nos. 462, 2004.

Frond cylindrical, tubular, simple, tapering to a filiform stipe below, above inflated, flexuous, and intestinelike; cells 6 to 8 by 8 to 12 mic., roundish polygonal, in longitudinal series; membrane somewhat thickened on the inside; chromatophore filling the thick-walled cell.

Florida; southern California; warmer waters generally.

Two or three small clumps, on rocks of Shackleford jetty, Beaufort, N. C., April, 1908. Fronds 6 to 23 cm. long.

This, being a southern species, might be expected to occur at Beaufort throughout the summer, but has been found only once, in April. Even then it was by no means a conspicuous part of the spring flora. It is distinguished from *E. intestinalis*, which it resembles, by having smaller cells arranged in regular series, a somewhat more delicate membrane, and a thicker wall between the cells.

3. **Enteromorpha intestinalis** (Linnæus) Link.

Ulva intestinalis, Linnæus, 1755, p. 432.
Enteromorpha intestinalis, Link, 1820, p. 5.
Enteromorpha intestinalis, Harvey, 1858, p. 57 (in part).
Ulva enteromorpha var. *intestinalis*, Farlow, 1882, p. 43.
Enteromorpha intestinalis, Wolle, 1887, p. 107, pl. 125, f. 9–10.
Enteromorpha intestinalis, De Toni, 1889, p. 123.
Enteromorpha intestinalis, Collins, 1909, p. 204.
P. B.-A. No. 464.

Frond simple or having at the base a few branches similar to the main frond, or occasionally a few proliferations above; length varying from a few centimeters to several meters; diameter 1 to 5 cm.; at first attached by a short, cylindrical stipe, but soon detached and floating; cylindrical or expanding above, more or less inflated, often much crisped and contorted, and irregularly and strongly constricted; cells 10 to 16 mic. in diameter, in no regular order; thickness of membrane varying from 50 mic. below to 20 mic. above; cells in cross section 12 to 30 mic.

Along the shores of North America, except, possibly, the south Atlantic coast; salt water lakes of western United States; Brazil; Europe; Japan.

Fairly abundant on rocks of Fort Macon jetties, Beaufort, N. C., December, 1908.

A very variable species, of which many forms have been described; some of these in fresh water.

4. **Enteromorpha linza** (Linnæus) J. Agardh.

Ulva linza, Linnæus, 1753, vol. 2, p. 1163.
Ulva linza, Harvey, 1858, p. 59.
Enteromorpha linza, J. Agardh, 1882, p. 134, pl. 4, f. 110–112.
Ulva enteromorpha var. *lanceolata*, Farlow, 1882, p. 43.
Enteromorpha linza, De Toni, 1889, p. 124.
Enteromorpha linza, Collins, 1909, p. 206.
P. B.-A. Nos. 16, 967.

Frond lanceolate or linear lanceolate, simple, 1 to 5 dm. long, 1 to 20 cm. broad; stipe short, hollow; upper part of the frond flat, the membranes grown together as in Ulva, except at the edges, where they remain free.

Maine to West Indies; Alaska to California; South America; Europe; Tasmania.

Abundant on rocks and shells in harbor and on jetties at Fort Macon and Shackleford, Beaufort, N. C., March to May, 1907–1909, at about low-water line; fairly abundant at about water level on buoy, Port Royal, S. C., August, 1909.

The forms of this species have been divided under forma *crispata*, with edges much crisped and folded, and forma *lanceolata*, edges even or folded, not crisped. Only the latter of these occurs at Beaufort. The smaller specimens look like forms of *E. intestinalis*, but in the latter the frond, though often collapsed, is tubular throughout; in *E. linza* the two membranes adhere except at the edges, where there is a narrow, open space, around which the cells are arranged in cross section nearly in a circle. Different plants vary greatly in their appearance, but the species is easily recognized by the above characters.

Genus 2. Ulva Linnæus.

Ulva, Linnæus, 1753, vol. 2, p. 1163.

Frond membranaceous, flat, consisting of two layers of cells, in any of which, except those in the thickened base, zoospores or gametes may be formed, issuing through an opening in the surface of the fronds, attached or free floating; surface entire or perforate.

Marine.

Seven species, some of them grading into each other, throughout the world.

KEY TO SPECIES.

Frond entire or irregularly lobed or laciniate....................................1. *U. lactuca* (p. 421).
Frond divided into distinct segments..2. *U. fasciata* (p. 422).

1. **Ulva lactuca** Linnæus.

Ulva lactuca, Linnæus, 1753, vol. 2, p. 1163.
Ulva latissima, Harvey, 1858, p. 59.
Ulva lactuca var. *lactuca*, Farlow, 1882, p. 43.
Ulva lactuca, De Toni, 1889, p. 111.
Ulva lactuca, Collins, 1909, p. 214, pl. 7, f. 75

SEA LETTUCE.

Frond very variable in shape, at first attached and generally of a lanceolate or ovate-lanceolate form; later of irregular shape and often detached and floating; the cells usually vertically elongate in cross section, seen from the surface, irregularly angular, closely set; thickness of the frond very variable.

In all seas.

Beaufort, N. C.: Abundant on rocks and on other algæ, Fort Macon and Shackleford jetties, throughout the year, usually not more than 2 to 4 cm. tall; abundant on Bogue Beach after winds; large pieces occasionally floating in the harbor, at times becoming fairly abundant; extremely abundant throughout harbor and on Fort Macon and Shackleford jetties, April and May, attached and floating, often up to 1 m. long; abundant in Newport River near Green Rock, August, 1906, forming large sheets resting on the bottom; and extremely abundant North River off Lennoxville, July, 1906, floating in large masses along shore. Pamlico Sound, Ocracoke, N. C.: Very abundant on shells, August, 1907. Core Sound, on jetty at Davis Island: Abundant, about 2 to 3 cm. tall. Wrightsville Beach, N. C.: Fairly abundant on shells in sound, July, 1909. Southport, N. C.: Very abundant, August, 1909. Georgetown, S. C.: Fairly abundant, August, 1909.

A very common plant throughout the world and extremely variable in form, thickness, and color. Two fairly marked types can be distinguished in the species as found with us on both Atlantic and Pacific coasts, connected by innumerable forms.

Var. **rigida** (Agardh) Le Jolis.

Ulva rigida, Agardh, 1820, p. 410 (in part).
Ulva lactuca, a *rigida*, Le Jolis, 1863, p. 38.
Ulva lactuca var. *rigida*, Farlow, 1882, p. 42.
Ulva lactuca forma *rigida*, De Toni, 1889, p. 111.
Ulva lactuca var. *rigida*, Collins, 1909, p. 215.
P. B.-A. Nos. 407, 2064.

Frond at first lanceolate or ovate; lanceolate, firm and stiff, with a distinct stipe; later somewhat irregularly divided, and often with numerous perforations of various sizes; cells vertically elongate in cross section.

Var. **latissima** (Linnæus) De-Candolle.

Ulva latissima, Linnæus, 1753, vol. 2, p. 1163.
Ulva lactuca var. *latissima*, De-Candolle, in Lamarck and De-Candolle, 1805, tome 2, p. 9.
Ulva lactuca var. *latissima*, Farlow, 1882, p. 43.
Ulva lactuca forma *genuina*, De Toni, 1889, p. 111.
Ulva lactuca var. *latissima*, Collins, 1909, p. 215.
P. B.-A. Fasc. D, No. LXXVI.

Frond irregular in outline, soon becoming detached and passing most of its life in a floating condition; thinner than var. rigida, lighter colored, and with cells nearer square in cross section.

Both of these forms seem to occur at Beaufort, but are not sharply distinguishable. In the immediate vicinity of Beaufort this species, like the species of Enteromorpha, reaches its greatest development in the spring months. At other times of the year it is present mostly in the form of specimens 2 to 4 cm. long attached to rocks. Large masses are, however, found in summer in adjoining waters and occasionally occur in Beaufort Harbor.

Many forms of the species approach closely in appearance to *U. fasciata* and slightly to *Enteromorpha linza.*

2. **Ulva fasciata** Delile.

Ulva fasciata, Delile, 1813, p. 153, pl. 58, f. 5.
Ulva fasciata, Harvey, 1858, p. 58.
Ulva fasciata, De Toni, 1889, p. 114.
Ulva fasciata, Collins, 1909, p. 216.
P. B.—A. No. 221.

Frond divided into more or less linear segments, margin smooth or undulate; in cross section the two layers of cells separate somewhat at the margin, which is rounded, with a small open space between the rows.

Florida; West Indies; California; warm waters all over the world.

Abundant in warm water of tide pool, northwest corner of "Town Marsh," Beaufort, N. C., resting on the bottom, summer.

A variable species varying from forms with a central axis and lateral lobes (as in a pinnately compound leaf) to forms having almost a continuous sheet with lobes few and inconspicuous, sometimes dichotomous; frond more or less perforate; lobes 5 mm. to 5 cm. in width; margin smooth and even or much crisped and undulate. (In this last form it corresponds to forms of *Enteromorpha linza.*) The structure of the frond is similar to that of *U. lactuca*, except the margin, which resembles *E. linza*. On the California coast it is hard to draw the line between this species and *U. lactuca*, either from the shape of the frond or from its structure. Four forms have been distinguished there, passing into each other more or less.

At Beaufort the species is easily distinguished by the much-crisped, lobed thallus with decidedly undulate margins, and by the structure of the frond at the margins. It forms sheets of considerable extent, with lobes long or short, broad or narrow, much crisped and much perforate. No specimens have been found with decidedly pinnate lobes like some of those occurring on the California coast. Some specimens approach forma *lobata* (P. B.-A. No. 863), but are more crisped and ruffled. Many lobes are long and narrow and much ruffled, resembling forma *tæniata* (P. B.-A. No. 862). The species has been observed at Beaufort only in summer; its condition at other times of the year is unknown. This is the most northern station reported for the species on our Atlantic coast, and is probably its northern limit.

Family 2. CHÆTOPHORACEÆ Wille.

Ulotrichiaceæ, De Toni, 1889, p. 151 (in part).

Fronds filamentous, except in a few doubtful forms, usually much branched, sometimes united in disklike expansions; cells uninucleate, with band-shaped or disk-shaped chromatophore, often somewhat divided or with projections; with one, rarely more pyrenoids; hairs almost always present, but varying in character; asexual propagation by four ciliate, in some cases biciliate, zoospores, by aplanospores, akinetes, and with special Palmella and Schizomeris stages in many genera; sexual reproduction in many genera by gametes, similar to the zoospores.

About 150 species, mostly fresh water, some marine, few aerial, etc., throughout the world.

A family of doubtful limits, being differently defined by nearly every author. The present treatment follows that of Collins (1909). The methods of reproduction seem to vary in different members, but are imperfectly known in the majority of cases.

KEY TO GENERA.

Thallus in cell wall of algæ	1. Endoderma (p. 423).
Thallus on shells, stones, etc.	2. Ulvella (p. 423).

Genus 1. **Endoderma** Lagerheim.

Endoderma, Lagerheim, 1883, p. 75.
Entoderma, Wille, in Engler and Prantl, 1897, p. 94.

Frond microscopic, creeping on or within other algæ or aquatic plants; filaments irregularly branched, with or without hairs; cell division mostly terminal; chromatophore a parietal layer with one or more pyrenoids; zoospores 2 to 4 ciliate, with stigma, formed four or more in a cell, escaping by a hole and soon germinating; sexual reproduction by biciliate motile gametes without stigma is probable, but not certain.

About 10 species, marine and fresh water.

Endoderma viride (Reinke) Lagerheim.

Entocladia viridis, Reinke, 1879, p. 476, pl. 6, f. 6–9.
Endoderma viride, Lagerheim, 1883, p. 75.
Endoderma viride, De Toni, 1889, p. 209.
Endoderma viride, Collins, 1909, p. 279.
P. B.-A. Nos. 1626, 2006, 2236.

Filaments usually much branched, 3 to 8 mic., usually 6 mic. diameter, cells 1 to 6 diameters long, sometimes cylindrical, more often irregularly swollen and contorted, with one pyrenoid; terminal cell blunt or tapering; growing in cell walls of various algæ.

Massachusetts; Europe.

Fairly abundant on each of four specimens of *Cladophora catenata* (?), Bogue Beach, Beaufort, N. C., August, 1907.

This species seems to have been recorded in North America only from Massachusetts. Its small size makes it easily overlooked, and it will probably be found widely distributed on the Atlantic coast.

Genus 2. **Ulvella** Crouan.

Ulvella, Crouan, 1859, p. 288.

Fronds forming small disks on larger plants or other objects, firmly attached by the under surface, originally monostromatic, of radiating, laterally united, dichotomous filaments; later polystromatic except at the margin; cells with parietal chromatophore and, in most species, one pyrenoid, arranged in more or less definite vertical series; biciliate zoospores formed in the central cells, 4 to 8 to 16 in a cell, escaping by an opening at the top. Marine.

Few (4 or more) species in North America and Europe.

Ulvella lens Crouan. Fig. 1.

Ulvella lens, Crouan, 1859, p. 288, pl. 22, f. 25–28.
Ulvella lens, De Toni, 1889, p. 148.
Ulvella lens, Collins, 1909, p. 286, pl. 11, f. 102.

Fronds orbicular, 1 to 3 mm. diameter, cells 15 to 20 mic. in diameter in center of frond, near the margin 10 to 15 by 20 to 30 mic., without pyrenoid; frond usually not over three layers thick in the center.

West Indies; Europe.

Occasionally forming a green coating on shells, Pamlico Sound, Ocracoke, N. C., August, 1907.

Except for a recent find by Börgesen in the Danish West Indies, this species is not recorded from any other locality in North America.

Order 2. **Siphonocladiales.**

Fronds multicellular, usually more or less branched; cells multinucleate, very rarely uninucleate, chromatophore net shaped, or of numerous small disks.

KEY TO FAMILIES.

Frond erect, zoospores and gametes produced in little changed vegetative cells.......................... 1. CLADOPHORACEÆ (p. 424).
Frond creeping, boring in shells, zoospores produced in distinct, ultimately detached sporangia.......................... 2. GOMONTIACEÆ (p. 429).

Family 1. CLADOPHORACEÆ (Hassall) De Toni.

Frond of simple or branching, monosiphonous filaments, free or more or less united laterally; cells multinucleate, rarely uninucleate, with chromatophore net form, or broken into many small portions, with many pyrenoids; asexual propagation by four ciliate zoospores (sometimes by biciliate?) and by akinetes; sexual reproduction by biciliate, usually similar gametes. Zoospores and gametes formed in little changed vegetative cells.

About 350 species, marine and fresh water, throughout the world.

KEY TO GENERA.

a. Filaments simple, firm .... *b*.
b. Filaments regularly cylindrical or clavate .... 1. Chætomorpha (p. 424).
bb. Filaments usually more or less irregular .... 2. Rhizoclonium (p. 427).
aa. Filaments branched .... *c*.
c. Branches usually short, rhizoidal .... 2. Rhizoclonium (p. 427).
cc. Branches of successive orders, but of the same character .... 3. Cladophora (p. 427).

Genus 1. **Chætomorpha** Kuetzing.

Chætomorpha, Kuetzing, 1845a, p. 203.

Frond of a single unbranched series of multinucleate cells, all but the usually longer basal cell capable of division; basal cell producing either a disk or more or less branched rhizoidal prolongations serving for attachment; frond always attached, or becoming loose and continuing in a free state; membrane thick, firm, usually distinctly lamellate; asexual propagation by four-ciliate zoospores, produced in little changed cells; sexual reproduction by similar biciliate gametes; akinetes sometimes formed (?).

About 50 species, mostly marine, rarely in fresh water, throughout the world from Arctic to Antarctic regions.

KEY TO SPECIES.

Filaments usually 400 to 500 mic. diameter, sometimes less, Beaufort material 120 to 240 mic.; coarse, wiry .... 1. *C. melagonium* (p. 424).
Filaments 125 to 400 mic. diameter, sometimes less, usually 200 to 250 mic., Beaufort material 80 to 110 mic.; yellowish green, soft, flaccid .... 2. *C. linum* (p. 425).
Filaments 125 to 175 mic. diameter, Beaufort material 100 to 175 mic.; dark green, soft, flaccid .... 3. *C. brachygona* (p. 426).

1. **Chætomorpha melagonium** (Weber and Mohr) Kuetzing. Fig. 2C.

Conferva melagonium, Weber and Mohr, 1804, p. 194, pl. 3, f. 2.
Chætomorpha melagonium, Kuetzing, 1845a, p. 204.
Chætomorpha melagonium, Harvey, 1858, p. 85.
Chætomorpha melagonium, Farlow, 1882, p. 46.
Chætomorpha melagonium, De Toni, 1889, p. 273.
Chætomorpha melagonium, Collins, 1909, p. 323.
P. B.-A. No. 412 (forma *typica*), No. 413 (forma *rupincola*).

Filaments erect, coarse and wiry, dark glaucous green, usually 400 to 500 mic. diameter; sometimes 300 mic. or less; cells 1 to 2 diameters long.

Common from New Jersey to Greenland; Alaska; northern Europe.

Abundant on rocks Shackleford jetty, Beaufort, N. C., forming dense masses with *Ulva lactuca*, *Enteromorpha prolifera*, and *E. linza*, about low-water level, May, 1907.

Two forms of the species are recognized: f. *rupincola* (Areschoug) Kjellman, growing attached and erect, usually quite straight; and f. *typica* Kjellman, unattached, lying loose in crisped, tangled masses. The latter form is apparently only a later stage of the plant. There is considerable variation in the size of the filaments, and the slender forms, sometimes as low as 300 mic. diameter or less, are not always easy to distinguish from *C. linum*; but the greater rigidity and the dark, glaucous, green color are usually sufficient marks.

The material from Beaufort is finer and less rigid than most specimens of this species from other localities, approaching in this respect *C. linum*, but is coarser and more rigid than most specimens of the latter species. The comparative width of the filaments is as follows: *C. melagonium*, 180 to 440 mic.; *C. linum*, 142 to 434 mic.; *C. melagonium* (Beaufort specimens), 120 to 240 mic. Both of the former have length of cells from slightly less than 1 to more than 2 diameters, the Beaufort specimens have length of cells from two-thirds to 2 diameters, the majority of cells being 1 diameter or less. In spite of these variations, there seems little doubt that the material from Beaufort belongs to this species, forma *rupincola*. It is easily distinguished from *C. linum* at Beaufort by its coarse, rigid, dark-green filaments.

It has been found at this place only in May, 1907, not being observed in April, 1908. This is a northern species, and the present locality is the most southern station reported for it. It is not improbable that this is its southern limit, although it may be found farther south in the winter or spring.

2. **Chætomorpha linum** (Mueller) Kuetzing.

Conferva linum, Mueller, in Flora Danica, tom. 5, p. 4, pl. 771, f. 2, 1782.
Chætomorpha linum, Kuetzing, 1845a, p. 204.
Chætomorpha sutoria, Harvey, 1858, p. 87.
Chætomorpha longiarticulata, Harvey, 1858, p. 86, pl. 46, E.
Chætomorpha olneyi, Harvey, 1858, p. 86, pl. 46, D.
Chætomorpha linum, Farlow, 1882, p. 47.
Chætomorpha linum, De Toni, 1889, p. 269.
Chætomorpha aerea f. *linum*, Collins, 1909, p. 325.
Chætomorpha linum, Collins, 1918, p. 79.
A. A. B. Ex. No. 175.
P. B.-A. Nos. 22, 1863 (*C. aerea* f. *linum*).

Filaments unattached, prostrate, light green, rather stiff, diameter 200 to 250 mic., cells about as long as broad.

Nova Scotia to West Indies; warm and temperate waters generally.

Rather rare, shoal south of laboratory, Beaufort, N. C., August, 1903 (?); marsh west of laboratory, August, 1907 (?).

This species apparently bears the same relation to *C. linum* f. *aerea* as the loose form of *C. melagonium* does to the attached form. It occurs in great masses of curled and crisped filaments in warm, shallow bays.

The Beaufort material probably belongs to this species, but was not found in sufficient quantity for a positive determination.

Forma **aerea** (Dillwyn) Collins. Fig. 2A.

Conferva aerea, Dillwyn, 1809, pl. 80.
Chætomorpha aerea, Kuetzing, 1849a, p. 379.
Chætomorpha aerea, Harvey, 1858, p. 86.
Chætomorpha aerea, Farlow, 1882, p. 46.
Chætomorpha aerea, De Toni, 1889, p. 272.
Chætomorpha aerea, Collins, 1909, p. 324, pl. 12, f. 115.
Chætomorpha linum f. *aerea*, Collins, 1918, p. 79.
P. B.-A. Nos. 76, 1526 (C. aerea).

Filaments attached, erect, yellowish green, 125 to 400 mic. or less in diameter, cells about as long as broad, base of filament usually more slender than the upper part; when producing zoospores the fertile cells are much inflated and nearly globular.

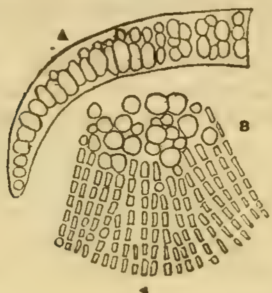
Maine to West Indies; California; warm and temperate waters generally.

Sometimes abundant on rocks between jetties at Fort Macon, summer and autumn, forming flaccid, tangled masses of filaments about 6 dm. above low water, and fairly abundant on sea buoy, September, 1905, Beaufort, N. C. Abundant on rocks in tide pool, Morris Island, 10 cm. above to 10 cm. below water level, water warm to touch, Charleston, S. C.

In habit like *C. melagonium*, but of somewhat smaller diameter, lighter color and softer texture; not firm enough to stand erect when taken from the water.

Of varying degrees of coarseness. The Beaufort material is finer than specimens from other localities, being 80 to 110 mic. wide, with cells 90 to 225 mic. long. In characters other than the size of the filaments, this material seems to agree with "*C. aerea*," as observed in herbaria, and is certainly more like that species than like any of the others recorded from North America. This is the finest of the three representatives of this genus occurring at Beaufort.

It seems somewhat irrational to consider a floating plant as the species and to refer the more natural, attached plant to a form. As was pointed out by Howe (1914, p. 99) this procedure is, however, required by the rules of botanical nomenclature, since *C. linum* was described before *C. aerea* and must, consequently, take precedence over the latter form.



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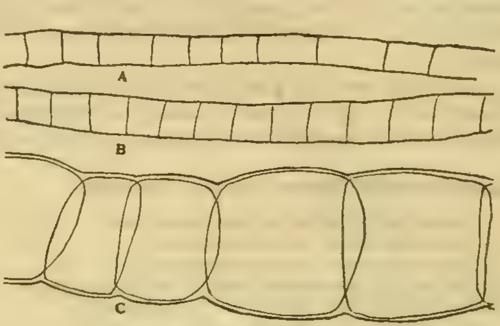

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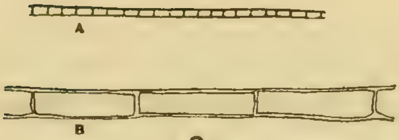

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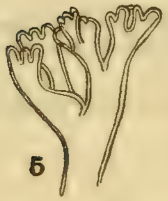

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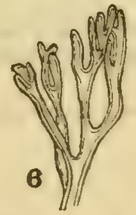

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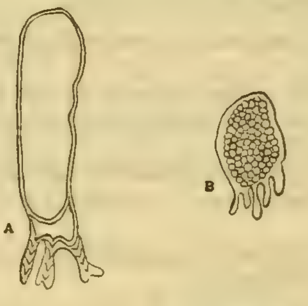

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Fig. 1.—*Ulvella lens*, after Crouan (1859). A, Section of thallus; B, Surface view.

Fig. 2.—A, *Chætomorpha linum* f. *aerea;* B, *Chætomorpha brachygona;* C, *Chætomorpha melagonium* f. *rupincola.* ×47.

Fig. 3.—*Rhizoclonium riparium.* A, ×47; B, ×281.

Fig. 4.—*Gomontia polyrhiza*, after Lagerheim (1885). A Vegetative cell; B, Aplanosporangium.

Fig. 5.—*Udotea cyathiformis*, ×78, after Howe (1909). Apices of cortical filaments of stipe.

Fig. 6.—*Udotea conglutinata*, ×78, after Howe (1909). Apices of cortical filaments of stipe.

3. **Chætomorpha brachygona** Harvey. Fig. 2B.

Chætomorpha brachygona, Harvey, 1858, p. 87, pl. 46a.
Chætomorpha brachygona, De Toni, 1889, p. 267.
Chætomorpha brachygona, Collins, 1909, p. 325.
P. B.-A. No. 622.

Filaments free, rigid, curved, and twisted, forming strata of some extent on rocks or among other algæ; cells 125 to 175 mic. diameter, quite uniformly as long as broad, except just after dividing.

Florida; West Indies; Mexico.

Rather abundant, mixed with other algæ floating in harbor, Beaufort, N. C., September and October, 1905; large, tangled mass Bogue Beach, September, 1906.

The material from Beaufort Harbor has the diameter of filaments 100 to 175 mic. This species, as it occurs there, is intermediate in appearance between *C. melagonium* and *C. linum* f. *aerea*, being finer, less rigid, and lighter green than the former, and coarser, more rigid, and darker green than the latter.

This is the most northern station reported for the species, and is probably its northern limit.

Genus 2. **Rhizoclonium** Kuetzing.

Rhizoclonium, Kuetzing, 1843, p. 261.

Filaments usually prostrate, consisting of a single series of multinucleate cells, with net-shaped chromatophore and several pyrenoids, unbranched or, in some species, with a few irregular branches similar to the axis, and with more or less numerous rhizoidal branches, which are mostly unicellular, but sometimes consist of several cells. Asexual propagation by biciliate zoospores, with stigma, escaping through an opening in the cell wall; also by akinetes; but in only a few species has either form of fructification been found.

About 25 species, in fresh or salt water or on moist earth, throughout the world.

The filaments resemble those of Chætomorpha, but are less uniformly cylindrical, there being almost always more or less irregularity in the form of the cells. The short rhizoidal branches, when present, clearly characterize the genus, but they are not always developed, and when they are absent, the resemblance to Chætomorpha is deceptive.

Rhizoclonium riparium (Roth) Harvey. Fig. 3.

Conferva riparia, Roth, 1806, p. 216.
Rhizoclonium riparium, Harvey, 1849, pl. 238.
Rhizoclonium riparium, Harvey, 1858, p. 92.
Rhizoclonium riparium, Farlow, 1882, p. 49, pl. 3, f. 2.
Rhizoclonium riparium, De Toni, 1889, p. 278.
Rhizoclonium riparium, Collins, 1909, p. 327.
A. A. B. Ex. No. 213.
P. B.-A. Nos. 24, 1734 (266,976, var. *implexum;* 1688, var. *validum*).

Filaments usually pale green, forming expansions on ground or rocks in the littoral zone; cells usually 20 to 25 mic. in diameter, rarely a little more or less, length 1 to 2 diameters; branches none or few or many.

Greenland to Florida; Alaska to Washington; California; South America; Europe; Borneo.

Fairly abundant on rocks of Shackleford jetty, Beaufort, N. C., April, 1908.

Three varieties are recognized, depending on the amount and nature of the branching; there is no typical form distinct from these.

It was not observed here in May, 1907, and has not been found in winter or summer.

Genus 3. **Cladophora** Kuetzing.

Cladophora, Kuetzing, 1843, p. 262.

Frond composed of filaments of a single series of cells, the filaments branching, usually abundantly; branching lateral, but often coming to appear dichotomous in consequence of the pushing aside of the original filament by the branch; attached at first, later attached or free floating; growth chiefly by division of the apical cell, subsequent division of cells being exceptional; branches all of the same type; cells multinucleate, the chromatophore either covering the cell wall or forming a network on it or broken into numerous small disks; pyrenoids several in a cell; asexual propagation by four-ciliate zoospores; sexual reproduction by similar biciliate gametes, uniting and germinating immediately, or sometimes germinating without copulation; portions of filaments sometimes capable of passing into resting condition, forming structures perhaps to be considered as akinetes.

Three hundred to 400 species described, many of them on insufficient characters, occurring in fresh and salt water throughout the world.

One of the largest genera of algæ and one of the most difficult. There are few sharply marked characters for distinguishing the species, it being mostly a question of more or less in one respect or another. It is impossible for one not familiar with the genus to determine the species without abundant authentic specimens for comparison.

KEY TO SPECIES.

a. Main filaments seldom reaching 150 mic. in diameter .... *b.*
  b. Main filaments distinctly angled or flexuous .... 1. *C. flexuosa* (p. 428).
  bb. Main filaments straight or nearly so .... 2. *C. crystallina* (p. 428).
aa. Main filaments 150 mic. or more in diameter .... *c.*
  c. Lower cells less than 10 diameters long .... 3. *C. fascicularis* (p. 428).
  cc. Lower cells 10 diameters long or more .... 4. *C. prolifera* (p. 429).

1. **Cladophora flexuosa** (Mueller) Harvey.

Conferva flexuosa, Mueller, in Flora Danica, tom. 5, pl. 882, 1782.
Cladophora flexuosa, Harvey, 1849a, p. 202.
Cladophora flexuosa, Harvey, 1858, p. 78.
Cladophora flexuosa, Farlow, 1882, p. 54.
Cladophora flexuosa, De Toni, 1889, p. 311.
Cladophora flexuosa, Collins, 1909, p. 339.
A. A. B. Ex. No. 206.
P. B.-A. Nos. 1076, 1527, 2239.

Fronds 10 to 20 cm. high, light green; main filaments 80 to 120 mic. diameter, regularly flexuous with flexuous alternate branches, 40 to 80 mic. in diameter, with alternate or secund, curved, and sometimes refracted ramuli; cells from 6 diameters long below to 2 diameters in the ramuli.

Newfoundland to Bermuda and Florida; Alaska; Europe.

Abundant, attached and floating masses, Mullet Pond, Shackleford Banks, and fairly abundant on rocks of Fort Macon jetties, Beaufort, N. C., about low-water line, April, 1908.

This species closely approaches several others of the genus, but as none of these similar species has been found at Beaufort, this fact need not give trouble there. Of the Beaufort species, it most nearly resembles *C. crystallina*, from which it is distinguished by its flexuous, alternate branches. It has been observed at Beaufort only in April, 1908, not being found there in May, 1907, and not being present in Mullet Pond in August, 1907.

2. **Cladophora crystallina** (Roth) Kuetzing. Pl. LXXXIV, fig. 1.

Conferva crystallina, Roth, 1797, p. 196.
Cladophora crystallina, Kuetzing, 1845a, p. 213.
Cladophora crystallina, De Toni, 1889, p. 318.
Cladophora crystallina, Collins, 1909, p. 342.
P. B.-A. Nos. 1581, 1865.

Fronds yellowish or whitish green, soft, glossy, 10 to 30 cm. high; filaments slightly matted, distantly dichotomously or trichotomously branched; main branches 80 to 140 mic. in diameter, tapering to 25 to 40 mic. in the ramuli; branching erect or patent; upper ramuli sometimes whorled or alternately secund; cells cylindrical, 4 to 12 diameters long.

Massachusetts; West Indies; Bermuda; Europe.

Abundant on sea buoy, Beaufort, N. C., July, 1907.

A variable species, but usually marked by its light color and silky gloss. It is distinguished from *C. flexuosa*, the Beaufort species which it most nearly resembles, by its dichotomous or trichotomous branching and its straight branches.

3. **Cladophora fascicularis** (Mertens) Kuetzing.

Conferva fascicularis, Mertens, in Agardh, 1824, p. 114.
Cladophora fascicularis, Kuetzing, 1843, p. 268.
Cladophora fascicularis, De Toni, 1889, p. 316.
Cladophora fascicularis, Collins, 1909, p. 345.
P. B.-A. Nos. 122, 1228, 1472.

Fronds elongate, up to 50 cm. long; main filaments and principal branches flexuous, sparingly alternately branched, the ends beset with rather long, pectinate, more or less densely fasciculate ramuli; main filaments 200 to 250 mic. in diameter, cells 2 to 4 diameters long; ramuli 80 to 120 mic. diameter, cells usually 1 to 2 diameters long.

Florida; West Indies; South America; Red Sea.

Abundant in bay at New Inlet, Southport, N. C., August, 1909, floating and attached to shells and grass, 7 cm. above to 7 cm. below low water.

This is the most northern station reported for this species.

4. **Cladophora prolifera** (Roth) Kuetzing.

Conferva prolifera, Roth, 1797, pl. 3, f. 2.
Cladophora prolifera, Kuetzing, 1845a, p. 207.
Cladophora prolifera, De Toni, 1889, p. 306.
Cladophora prolifera, Collins, 1909, p. 348.

Fronds dense, dark green when growing, blackish when dried, up to 20 cm. high, rarely more; filaments coarsely membranaceous or cartilaginous, 300 to 400 mic. in diameter, dichotomous or trichotomous, divisions mostly erect, more frequent toward the somewhat fastigiate tips; ramuli 130 to 200 mic. diameter, blunt; cells up to 20 diameters long in the main filaments, much shorter in the branches, 4 to 6 diameters long in the ramuli.

Porto Rico; Barbados; Mediterranean; Red Sea.

Bogue Beach, Beaufort, N. C., two fragments, August and September, 1904, four small fragments, August, 1907(?).

A coarse, dark species, distinguished with comparative ease.

Besides the above-mentioned species, material of Cladophora, insufficient for specific determination, has been found at Fort Macon, on the buoys, on Bogue Beach, floating in Beaufort Harbor, and at Ocracoke. A few specimens gathered on Bogue Beach, August, 1907, resemble *C. catenata* (Ag.) Ardis., but are not included among the descriptions, since they are insufficient for a satisfactory determination. A small amount of Cladophora was collected in the harbor in January, 1909, but at no other time during the winter. Except for such scanty material, which is fairly constant on the sand breaks and rocks at Fort Macon during the summer and autumn, all the species of Cladophora at Beaufort seem to be transient visitors. None has been found there in any two successive years.

Family 2. GOMONTIACEÆ Bornet and Flahault.

Fronds consisting of creeping, branched filaments, penetrating various shells, in one species penetrating wood; cells multinucleate; asexual propagation by biciliate zoospores or possibly by aplanospores, both produced in sporangia formed usually on the upper surface of the horizontal layer; sexual reproduction by biciliate gametes (?).

Genus **Gomontia** Bornet and Flahault.

Gomontia, Bornet and Flahault, 1888a, p. 164.

Filaments usually radiating, irregularly branched; aplanospores develop directly into vegetative filaments, or first form new aplanosporangia (?).

Six species, mostly marine, two in fresh water, North America and Europe.

The observations of Moore (1918) tend to alter the previous conception of this genus, indicating that the structures previously regarded as aplanospores are formed from zoospores which pass into a resting condition and delay their germination for an indefinite time. No evidence for the existence of gametes was obtained by this author.

Gomontia polyrhiza (Lagerheim) Bornet and Flahault. Fig. 4.

Codiolum polyrhizum, Lagerheim, 1885, p. 22, pl. 28.
Gomontia polyrhiza, Bornet and Flahault, 1888a, p. 163.
Gomontia polyrhiza, Bornet and Flahault, 1889, p. CLII, pls. 6–8.
Gomontia polyrhiza, De Toni, 1889, p. 389.
Gomontia polyrhiza, Collins, 1909, p. 370, pl. 15, f. 135.
P. B.-A. No. 315.

Filaments 4 to 8 mic. in diameter; sporangia 30 to 40 mic. in diameter; zoospores of two sorts, one 10 to 12 by 5 to 6 mic., the other about 5 by 3.5 mic.; development not known; the smaller ones possibly gametes(?); aplanospores 4 mic. in diameter.

Abundant on both coasts of North America; Europe.

In shells, Pamlico Sound, Ocracoke, N. C., August, 1907.

Order 3. Siphonales.

Fronds filiform, usually much branched or interwoven into various forms, usually continuous without dissepiments in the vegetative condition, multinucleate, with many lens or disk shaped chromatophores.

The members of this order are, with few exceptions, marine and are mostly confined to tropical and warm temperate regions.

KEY TO FAMILIES.

a. Frond differentiated into root, stem, and branches of varied form ....4. CAULERPACEÆ (p. 434).
aa. Frond not differentiated into root, stem, and branches .... *b*.
b. Filaments interwoven to form fronds of definite form ....3. CODIACEÆ (p. 431).
bb. Filaments branching plumosely, not interwoven ....2. BRYOPSIDACEÆ (p. 431).
bbb. Filaments branching dichotomously or irregularly, forming indefinite mats ....1. DERBESIACEÆ (p. 430).

Family 1. DERBESIACEÆ Thuret.

Vegetative frond mostly unicellular, irregularly or dichotomously branched, forming indefinite mats, or consisting of upright branches arising from creeping filaments attached to the substratum by short, irregular branches; chromatophores large or small disks, each containing 1 to 3 pyrenoids, or lacking these; asexual propagation by means of almost spherical zoospores, formed (8 to 20) in sporangia arising as lateral branches of definite shape and cut off from the main filaments by cross walls, each zoospore possessing a circle of cilia and germinating immediately; sexual reproduction unknown.

About nine species, all marine, in North America, Europe, and Asia.

Genus **Derbesia** Solier.

Derbesia, Solier, 1847, p. 157.

Characters of the family.

About nine species.

Derbesia turbinata Howe and Hoyt. Pl. CXV, figs. 10–16.

Derbesia turbinata, Howe and Hoyt, 1916, p. 106, pl. 11, figs. 10–16.
Derbesia turbinata, Collins, 1918, p. 92.

Frond more or less creeping, forming straggling mats 8 to 9 cm. broad (or high?) the basal parts sometimes here and there resolved into cysts; filaments 16 to 100 mic. (mostly 40 to 55 mic.) in diameter, sparingly branched, the branching subdichotomous or more often lateral, the lateral branches usually without a basal septum, the others with or without one or two septa above the dichotomy; chloroplasts at first orbicular elliptic or ovate, 5 to 7 mic. in diameter, later irregularly confluent and spindle shaped; zoosporangia turbinate, broadly obconi-obovoid, broadly pyriform, or pestle shaped, 137 to

192 mic. long (excluding stalk), 124 to 164 mic. broad, mostly about as broad as long, the apex subtruncate, the outline commonly somewhat obdeltoid; pedicel mostly 15 to 33 mic. (rarely 75 mic.) long, 16 to 22 mic. broad, the pedicel cell usually about 19 to 22 mic. long and broad or sometimes broader than long (11 by 22 mic.); zoospores unknown; color dark green or olive green.

Several small mats mixed with Cladophora sp. dredged from coral reef offshore, Beaufort, N. C., August 11, 1914.

Endemic.

Family 2. BRYOPSIDACEÆ (Bory) De Toni.

Vegetative frond unicellular, much branched; chromatophores numerous small disks, each with one pyrenoid; the axis producing below rhizoids, and above branches both of unlimited and limited growth; in the latter large biciliate, green, female gametes, and usually(?) on separate individuals, smaller, brown, biciliate male gametes are developed; by the union of the two a zygote is formed, germinating immediately.

About 30 species, all marine, especially in warmer seas.

Genus **Bryopsis** Lamouroux.

Bryopsis, Lamouroux, 1809a, p. 133.

Characters of the family; cavity continuous, without dissepiments, in the vegetative condition.

Twenty to 30 species.

Bryopsis plumosa (Hudson) Agardh. Pl. LXXXIV, fig. 4.

Ulva plumosa, Hudson, 1762, p. 571.
Bryopsis plumosa, Agardh, 1822, p. 448.
Bryopsis plumosa, Harvey, 1858, p. 31, pl. 45, A.
Bryopsis plumosa, Farlow, 1882, p. 59, pl. 4, f. 1.
Bryopsis plumosa, De Toni, 1889, p. 431.
Bryopsis plumosa, Collins, 1909, p. 403, pl. 17, f. 155.
P. B.-A. No. 227.

Frond seldom over 10 cm. high, rich, glossy green; amount of branching variable; typical forms with numerous lateral branches and often a second series; all branches with abundant distichous ramuli, shorter above, giving the branches triangular outlines.

Maine to Florida; Europe.

Two or three large masses in harbor, Beaufort, N. C., growing under a wharf, 7 to 10 cm. below low water, April, 1908.

The most widely distributed species of the genus; it is nowhere very abundant, but occurs in various stations. In its northern range it seems to be more specially a summer plant, but is sometimes found at any season. Variable in appearance.

At Beaufort this species has not been found in summer, autumn, or winter, and was not observed in May, 1907.

Family 3. CODIACEÆ Zanardini.

Spongodiaceæ, De Toni, 1889, p. 488.
Udoteaceæ, De Toni, 1889, p. 499.

Frond of definite shape, except in the lowest forms, composed of interwoven, continuous, branching filaments, sometimes apparently pluricellular by constrictions, calcified or not; asexual propagation by zoospores and aplanospores, formed in sporangia; sexual reproduction by motile gametes, either similar or differing in size.

About 80 species, all marine, in tropical and subtropical regions, especially in warm seas.

KEY TO GENERA.

Not calcified nor stipitate, soft and spongy; cortical layer formed of the swollen ends of the longitudinal filaments; filiform or somewhat flattened........................1. Codium (p. 432).
Calcified and stipitate; cortical layer formed of lateral branches, usually smaller than the longitudinal filaments; lamina fan shaped..2. Udotea (p. 433).

Genus 1. Codium Stackhouse.

Codium, Stackhouse, 1797, p. XVI.

Frond of spongy texture, of very varying form, consisting of branching, continuous filaments, their swollen ends—"utricles"—closely packed to form a cortical layer; no asexual propagation known; sexual reproduction by motile biciliate gametes, produced in subovoid gametangia, borne laterally on the utricles and separated from these by cross walls; female gametes large, dark green; male gametes small, yellowish; the zygote, formed by the union of a male and a female gamete, germinates immediately; female gametes sometimes germinate parthenogenetically(?); male and female gametes usually produced on different individuals, but sometimes on the same individual.

About 30 species described, many on insufficient characters; in tropical and temperate seas, mostly in warmer regions. This is the most northern station reported for the genus in North America, and is probably its northern limit.

The elongated forms of this genus are very variable. The characters on which many species have been described—the length of frond, amount of flattening, and comparative length and breadth of utricles—vary greatly and are often connected by intermediate stages.

At Beaufort the plants can be grouped around two types and are accordingly described as two species, although it is by no means certain that these should be kept distinct.

KEY TO SPECIES.

Frond more or less cylindrical except in the axils of the branches, abundantly branched .... 1. *C. tomentosum* (p. 432).
Frond more or less flattened, sparingly branched .... 2. *C. decorticatum* (p. 433.)

1. **Codium tomentosum** (Hudson) Stackhouse. Pl. LXXXV, fig. 1.

Fucus tomentosus, **Hudson**, 1732, p. 584.
Codium tomentosum, **Stackhouse**, 1797, p. XXIV.
Codium tomentosum, **Harvey**, 1858, p. 29 (in part).
Codium tomentosum, **De Toni**, 1889, p. 491.
Codium tomentosum, **Collins**, 1909, p. 388.
P. B.-A. Nos. 168, 1869.

Frond erect, cylindrical, dichotomously branched, more or less fastigiate; surface smooth and soft; utricles obovate-clavate, 100 to 150 mic., rarely 200 mic. in diameter(?), 3 to 6 diameters long, apex obtuse, unarmed.

North Carolina to Florida; West Indies; Europe; Asia; Africa; Oceanica.

Beaufort, N. C.: Very abundant, attached to rocks, shells, etc., throughout harbor and on Fort Macon jetties; less abundant on Shackleford jetties; very abundant on Bogue Beach after hard winds. Wrightsville Beach, N. C.: Abundant in sound, July, 1909. Pawleys Island, near Georgetown, S. C.: Fairly abundant in bay near inlet, August, 1909.

This is the northern limit of this species reported for North America. It is common at Beaufort from June to September, becoming less abundant during the autumn, and found only occasionally during the winter and spring. The only trace of these plants observed in April, 1908, was a group of minute specimens, 3 to 12 mm. long, on shells 15 cm. below low water, apparently just commencing their growth. In May, 1907, no specimens were found in the harbor, but three pieces, 2 to 3 cm. long, were dredged on the coral reef offshore, and a few small fragments were collected on Bogue Beach. Small specimens were collected in Beaufort Harbor and on Fort Macon jetties in January and February, 1909, but none was found at any other time during the winter. This may grow to a considerable size. The plant figured on Plate LXXXV, figure 1, found on Bogue Beach in October, had a radius of 30 cm. and, after the surface water was removed with a towel, weighed 1.942 kg. (4 pounds 4.5 ounces).

The species is distinguished from *C. decorticatum* by its more rounded, more densely branched thallus, and sometimes by its smaller utricles. The extremes of these species are very different in appearance, but they are connected by numerous intermediate forms so that it is often very difficult to decide to which species a given specimen should be referred, especially since the utricles may vary greatly in size, and the thallus is always more or less flattened below the dichotomies.

2. **Codium decorticatum** (Woodward) M. A. Howe. Pl. LXXXV, fig. 2.

Ulva decorticata, Woodward, 1797, p. 55.
Codium elongatum, Agardh, 1822, p. 454.
Codium elongatum, De Toni, 1889, p. 496.
Codium elongatum, Collins, 1909, p. 388.
Codium decorticatum, Howe, 1911, p. 494.
Codium decorticatum, Collins, 1912, p. 99.
P. B.-A. Nos. 627 (*C. elongatum*), 2017.

Frond dichotomously branched, often much elongate, younger divisions terete, older ones flattened, especially below the dichotomies, being there distinctly cuneate; utricles obovate-clavate, 300 to 400 mic. in diameter(?), five to six times as long as the greatest diameter.

North Carolina to Florida; West Indies; Lower California, Mexico; South America; Europe; Africa.

Beaufort, N. C.: Abundant on Bogue Beach after winds; occasional in Beaufort Harbor in earlier years, becoming more abundant in later years; abundant on rocks of Fort Macon jetties, July, 1909; and very abundant in harbor off Duncan breakwater and north of laboratory, September, 1909. Pawleys Island, near Georgetown, S. C.: Abundant in bay near inlet, August, 1909.

This is the northern limit of the species reported for North America.

The species is distinguished from *C. tomentosum* by the greater flattening, the more elongate, less densely branched frond, and sometimes by the larger utricles. The younger plants resemble *C. tomentosum*, but the flattening is marked in older plants; in some cases all parts except the younger tips are quite broadly cuneate. As, however, all plants of both species are more or less flattened below the dichotomies, and numerous intermediate forms are found, it is often difficult to determine on this basis to which species a given specimen should be referred. One specimen found at Beaufort had three main divisions, two of which were flattened like *C. decorticatum*, while the third resembled *C. tomentosum*. Dried specimens are particularly unreliable in this respect, since in these the amount of flattening may be largely due to the amount of pressure to which the plants were subjected during drying.

The size of the utricles furnished no criterion for distinguishing the plants of this region. While those on the coarsest, widest specimens are wider, those on other individuals having the form of *C. decorticatum* are narrower than many of those on individuals having the typical form of *C. tomentosum*.

If the two extreme forms found at Beaufort grade into each other in other localities as much as they do at this place, it may be questioned whether the present species is not merely a large form of *C. tomentosum*. On the other hand, however, the fact that it was first found at Beaufort on Bogue Beach and only in later years made its appearance in the harbor, indicates that it is a distinct species and that it established itself in this region during the period of this study. It seems, too, to appear here later in the spring and to disappear earlier in the fall than *C. tomentosum*. On this basis the intermediate forms may possibly be ascribed to hybridization.

This species may grow to a large size. One specimen collected on a jetty at Fort Macon had a length of 1 meter and a width of 5 cm. below its widest dichotomy.

Genus 2. **Udotea** Lamouroux.

Udotea, Lamouroux, 1812, p. 186.

Frond arising from a mass of rhizoids, differentiated into stipe and flabellum; stipe erect, with distinct cortex, terminating in a fan-shaped, more or less distinctly zonate flabellum, consisting of continuous, branching filaments, with more or less numerous short branches attached to each other by short processes and sometimes developing laterally into a more or less definite cortex; calcification more or less complete; reproduction unknown.

About 12 species, in tropical and warm temperate seas; seven of the species occur in North America.

This is the northern limit of the genus on this continent.

Udotea cyathiformis Decaisne. Fig. 5; Pl. LXXXIV, figs. 2 and 3.

Udotea cyathiformis, Decaisne, 1842a, p. 106.
Udotea conglutinata, Harvey, 1858, pl. 40 C (probably).
Udotea cyathiformis, De Toni, 1889, p. 512.
Udotea cyathiformis, Collins, 1909, p. 395.

Fronds 3 to 17 cm. high, greenish or whitish, more or less calcified; stipe mostly subterete, sometimes slightly flattened above, 0.2 to 5 cm. long, 1 to 6 mm. wide, corticated; transition from stipe to flabellum abrupt, flabellum uncorticated, cyathiform, now and then 1 to 5 cleft nearly or quite to the base, or more often early divided to base on one side and becoming almost flat, but usually remaining more or less concavo-convex at extreme base, then obovate, semiorbicular, or variously shaped, 1 to 11 cm. long, 1 to 9 cm. wide, mostly entire, often irregularly laciniate, rather faintly or not at all zonate; filaments of flabellum 40 to 135 mic. (mostly 60 to 100 mic.) in diameter, in several or many layers, nearly straight, parallel and rigid, somewhat flexuous and interwoven, distinct, each filament surrounded by a calcareous sheath which is perforated by numerous pores; branches of the stipe cortex in compact cymose-fastigiate clusters, the ultimate divisions scarcely longer than broad, truncate, truncate-obtuse, or very commonly with expanded truncate-capitate apices.

Florida; West Indies.

Dredged on coral reef offshore, Beaufort, N. C., about 15 specimens, 1 to 3 cm. long, May, 1907; 2 specimens, 4.5 cm. long, August, 1914.

This is the only species of Udotea that has been found in this region, but others are liable to occur. Most of them may be distinguished from the present species with comparative ease by means of the description given above; but one, *U. conglutinata*, closely resembles the present form and is liable to be confused with it. These species are, according to Howe (1909), distinguished as follows: *U. cyathiformis* has a goblet-shaped frond (sometimes split and more or less flattened), with abrupt transition in structure from stipe to flabellum; the corticating filaments of the stipe are compactly cymose-fastigiate, the ultimate divisions being scarcely longer than broad, obtuse, and often expanded at the apices (fig. 5). *U. conglutinata* has a flattened frond, with gradual transition in structure from stipe to flabellum; the corticating filaments of the stipe are somewhat loosely and irregularly fastigiate, the ultimate divisions being finger shaped, rather acute at apices (fig. 6). In difficult specimens these characters of the stipe cortex are especially useful in determining the species. Howe (1909) has given excellent descriptions and figures of these two species.

Family 4. CAULERPACEÆ (Reichenbach) De Toni.

Frond tubular, multinucleate, unicellular, traversed by cross strands of cellulose; multiplication apparently only by fragmentation of the frond; no asexual propagation or sexual reproduction known.

Only one genus.

Genus **Caulerpa** Lamouroux.

Caulerpa, Lamouroux, 1809b, p. 141.

Frond composed of a creeping stolon (wanting in one species), giving out rhizoids below and branches above, the latter of various form, usually erect, but sometimes prostrate, simple or branched.

About 80 species, in tropical and subtropical seas.

Caulerpa prolifera (Forskaal) Lamouroux.

Fucus prolifer, Forskaal, 1775, p. 193.
Caulerpa prolifera, Lamouroux, 1809b, p. 142.
Caulerpa prolifera, Harvey, 1858, p. 16, pl. 38 B.
Caulerpa prolifera, De Toni, 1889, p. 450.
Caulerpa prolifera, Collins, 1909, p. 413, pl. 18, f. 160.
P. B.-A. Nos. 269, 1872.

Stolon usually stout, naked, erect branches flat, linear, obtuse, up to 30 cm. long and 3 cm. wide, rarely divided, margin entire, sometimes slightly undulate, similar branches often arising proliferously from any point on the original branches; color blackish or olive green.

Florida; West Indies; Yucatan; Atlantic coast of northern Africa; Mediterranean.

One fragment of an upright branch, Bogue Beach, Beaufort, N. C., April, 1908.

It seems improbable that the fragment found here grew in this region at this season of the year; it seems much more probable that it was brought here by the Gulf Stream from Florida or the West Indies. This is the most northern point reported for the species or the genus.

Division III. PHÆOPHYCEÆ (Thuret) Kjellman.

Zoosporeæ, Farlow, 1882, p. 40 (in part).
Oosporeæ, Farlow, 1882, p. 98 (in part).
Fucoideæ, De Toni, 1895, p. 1.

Brown Algæ.

Algæ olivaceous brown, containing in their cells endochrome composed of chlorophyll and a characteristic brown pigment, fucoxanthin; endochrome contained in definite chromatophores; thallus varying extremely in size and form; cells containing mostly only one nucleus. Multiplication asexual or sexual: asexual (propagation) by motile noncopulating biciliate zoospores, or by aplanospores, or by specialized or nonspecialized portions of the thallus; sexual (reproduction) by zygotes formed by the copulation of gametes; gametes similar (isogametes), or different in form, size, etc.—that is, male and female (heterogametes)—usually motile, in some families differentiated into large nonmotile eggs and small motile sperms; all motile cells, zoospores or gametes, have two laterally inserted cilia except among the Dictyotaceæ where the sperms are monociliate; zoospores, aplanospores, and gametes produced in special organs (sporangia or gametangia) which are borne on ordinary portions of the thallus or on more or less specialized portions; asexual and sexual organs occurring on different individuals or, less often, on the same individual; in some forms, sexual and asexual generations alternating with each other in the life cycle; male and female gametes, when present, produced on the same or on different individuals; almost exclusively marine, some endophytic, a very few in fresh water.

About 1,000 species throughout the world, but reaching their greatest development in cold seas.

KEY TO ORDERS.

Asexual propagation by biciliate zoospores, rarely by nonmotile aplanospores; sexual reproduction usually by motile similar or dissimilar gametes, in one family by nonmotile eggs and motile biciliate sperms; sporangia and gametangia occurring on superficial portions of the thallus or arising from the transformation of surface cells..............1. Phæosporeæ (p. 436).

Asexual propagation lacking; sexual reproduction by nonmotile eggs and biciliate motile sperms; gametangia arising in sunken conceptacles usually on more or less specialized portions of the thallus..2. Cyclosporeæ (p. 449).

Asexual propagation by nonmotile aplanospores; sexual reproduction by nonmotile eggs and motile monociliate sperms; sporangia and gametangia arising from the transformation of surface cells, occurring singly or in groups, usually on ordinary portions of the thallus...3. Dictyotales (p. 453).

Order 1. **Phæosporeæ** Thuret.

Phæozoosporinæ, De Toni, 1895, p. 293.

Thallus multicellular (in a few forms one to few celled), varying greatly in size and form; asexual propagation by fragments of the thallus or special "brood buds" (propagula) or by laterally biciliate zoospores, or by nonmotile aplanospores; sexual reproduction by motile, laterally biciliate gametes, similar or differing in form and size, or by nonmotile eggs and laterally biciliate motile sperms; spores and gametes produced in organs (sporangia, gametangia) formed from ordinary vegetative cells or from special cells; sporangia and gametangia occurring on superficial portions of the thallus or arising from the transformation of surface cells.

KEY TO FAMILIES.

a. Sporangia and gametangia occupying the place of branches of the frond or formed by the transformation of segments or portions of these segments; longitudinal growth intercalary........1. Ectocarpaceæ (p. 436).

aa. Sporangia and gametangia formed by the transformation or division of a superficial cell, less often arising from the evolution of single segments of a segmented portion of the frond; longitudinal growth by intercalary division equally distributed through the whole frond or persisting a longer time at the base; frond simple.......2. Encœliaceæ (p. 442).

aaa. Sporangia and gametangia occupying the place of assimilating filaments or formed by the partial transformation of assimilating filaments........*b.*

  b. Longitudinal growth basal or lasting longest at the base........3. Elachisteaceæ (p. 444).

  bb. Longitudinal growth terminal or subterminal........4. Chordariaceæ (p. 445).

aaaa. Sporangia and gametangia lateral on special segmented filaments arising from the frond........*c.*

  c. Longitudinal growth subterminal........5. Stilophoraceæ (p. 447).

  cc. Longitudinal growth trichothallic; brushes of confervoid filaments at the ends of the short branches........6. Sporochnaceæ (p. 448).

Family 1. ECTOCARPACEÆ (Agardh) Hauck.

Frond consisting of a creeping filament, usually with more or less conspicuous upright filaments arising from this, or of a one or two layered disk; usually monosiphonous, occasionally divided once or twice here and there in a longitudinal direction; more or less branched or subsimple; growth in length by intercalary division; sporangia and gametangia occupying the place of branches of the frond, or formed by the transformation of articulations or segments of these articulations; organs of fructification consisting of "unilocular sporangia," formed by the growth of a cell without formation of cross walls, or of "plurilocular sporangia," formed by the growth and repeated division of one or more cells; these usually occurring on different individuals, sometimes apparently on the same individual; male and female gametes produced on the same or different individuals.

About 130 species described, many of them doubtful, in all seas, but most abundant in the North Atlantic, mostly epiphytic.

The method of reproduction is exceedingly various, even within a single genus. The family seems to show the beginning of differentiation into asexual and sexual cells. The products of the "unilocular sporangia" are asexual, either motile zoospores or nonmotile aplanospores. The products of the "plurilocular sporangia" are asexual or sexual, being all alike, giving either zoospores or isogametes, or of two sizes, giving either zoospores of two sizes or heterogametes, or of three sizes, giving zoospores of two sizes and possibly small gametes(?). Occasionally gametes, either male or female, may germinate without fusion. In addition to these, aplanospores may be formed in the "plurilocular sporangia." Both "unilocular" and "plurilocular" sporangia are formed in special branches or in portions of ordinary branches.

KEY TO GENERA.

Basal portion of the frond a filament expanded on the surface of the substratum; sporangia formed from special branches .... 1. Ectocarpus (p. 437).
Basal portion of the frond a filament penetrating within other algæ .... 2. Streblonema (p. 440).
Frond consisting of horizontal, more or less crowded, filaments, forming irregular or somewhat disklike patches on the surface of the host .... 3. Phæostroma (p. 442).

Genus 1. **Ectocarpus** Lyngbye.

Ectocarpus, Lyngbye, 1819, p. 130.

Thallus consisting of few or many simple or branched upright filaments arising from a horizontal filament; attached to substratum by the horizontal filament, often assisted by rhizoidlike processes from the bases of the upright filaments; longitudinal growth in the upright filaments intercalary, in the horizontal filaments apical; filaments usually monosiphonous, very rarely polysiphonous by longitudinal walls here and there; asexual propagation by laterally biciliate zoospores and nonmotile aplanospores produced in "unilocular sporangia;" sexual reproduction by laterally biciliate motile gametes, similar or differing in size, etc., produced in "plurilocular sporangia;" both organs of fructification occurring in the place of branches, always singly, usually on different individuals, sometimes apparently on the same individual; "unilocular sporangia" usually globose, ellipsoid, or short pyriform, sessile or shortly pedicillate, opening by an apical pore; "plurilocular sporangia" various in form, usually ovoid or silique form, or narrowly subuliform, sessile, or pedicillate, usually opening by an apical pore, sometimes tapering at the apex to a segmented hair.

Numerous species described, but many on insufficient characters, about 40 to 70 recognized; in all seas, especially the North Atlantic.

An extremely difficult genus which has not yet received sufficient study to establish order among the innumerable forms occurring in it. One not familiar with the genus can scarcely hope to determine the species. Fruiting specimens are always necessary. The fruits are microscopic.

KEY TO SPECIES.

a. Frond 2 to 5 cm. tall, rarely more; "plurilocular sporangia" clavate, broad, obtuse or truncated at the apex, sessile .... 1. *E. duchassaingianus* (p. 437).
aa. Frond usually 5 to 30 cm. and more tall .... *b*.
  b. "Plurilocular sporangia" conical-subulate, rarely short ovate, often tapering to a hair .... 2. *E. siliculosus* (p. 438).
  bb. "Plurilocular sporangia" short subulate or fusoid, not tapering to a hair .... 3. *E. confervoides* (p. 439).
  bbb. "Plurilocular sporangia" elliptical oblong, obtuse .... 4. *E. mitchellæ* (p. 439).

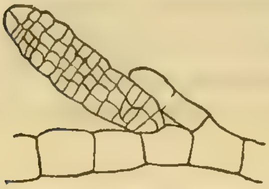
1. **Ectocarpus duchassaingianus** Grunow. Fig. 7.

Ectocarpus duchassaingianus, Grunow, 1867, p. 45, pl. 4, f. 1.
Ectocarpus duchassaingianus, De Toni, 1895, p. 545.
P. B.-A. Nos. 985, 2077.

Frond 1.5 to 4 cm. tall, forming muddy, dirty-looking tufts; branches spreading, usually short; diameter of filaments 15 to 34 mic., lower cells 2 to 3 diameters long, median ones 1 to 1.5 diameters, apical ones 3 to 4 diameters; sporangia of both kinds occurring on the same individual; "unilocular sporangia" ovate, sessile; "plurilocular sporangia" clavate, broad, obtuse or truncated at the apex, sessile, divided into numerous cells zonately arranged.

West Indies; Guadeloupe.

Fairly abundant on marine grasses, Newport River, near Green Rock, Beaufort, N. C., August, 1906.



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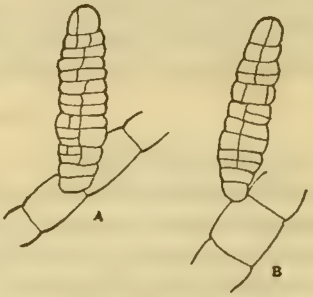

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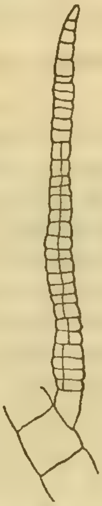

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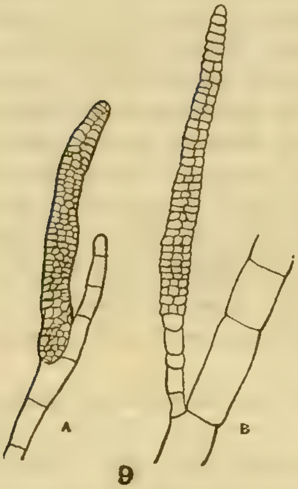

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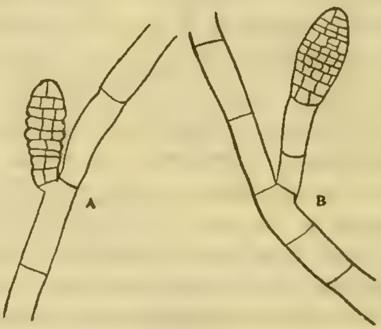

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Fig. 7.—*Ectocarpus duchassaingianus*, "plurilocular sporangium," × 279.

Fig. 8.—*Ectocarpus siliculosus*, "plurilocular sporangium," × 279.

Fig. 9.—*Ectocarpus confervoides*, "plurilocular sporangia," × 279. A, Sessile; B, Shortly pedicellate.

Fig. 10.—*Ectocarpus mitchellæ*, "plurilocular sporangia," × 279.

Fig. 11.—*Ectocarpus* sp. from coral reef, 1914, "plurilocular sporangium," × 279.

This species can be distinguished from the others occurring at Beaufort by its small size, muddy appearance, tufted branches, and the shape of "plurilocular sporangia."

This is the northern limit reported for the species.

2. Ectocarpus siliculosus (Dillwyn) Lyngbye. Fig. 8.

Conferva siliculosa, Dillwyn, 1809, Supplement, p. 69, pl. E.
Ectocarpus siliculosus, Lyngbye, 1819, p. 131, pl. 43 C (excluding var. β and synonyms).
Ectocarpus viridis, Harvey, 1852, p. 140, pl. 12 B, C.
Ectocarpus confervoides var. *siliculosus*, Farlow, 1882, p. 71.
Ectocarpus siliculosus, De Toni, 1895, p. 549.
P. B.-A. Nos. 319, 1386, 2294.

Fronds 3 to 30 cm. long, yellowish or from brownish to olivaceous, forming flaccid tufts, attached or floating free; branching distinctly lateral or pseudodichotomous below; branches alternate or unilateral, not opposite, often arcuately ascending; filaments 40 to 60 mic. in diameter; cells about 1 diameter long in the upper portion of the frond, often 4 to 5 diameters long below, somewhat constricted at the septa; sporangia of both kinds usually on the same individual; "unilocular sporangia" 30 to 65 (usually 50) mic. by 20 to 27 mic., ovoid or ellipsoid, sessile, or pedicillate; "plurilocular sporangia" 50 to 600 (usually 200) mic. by 12 to 25 mic., conical-subulate, rarely short ovate, sometimes slightly arcuate, often tapering to a hair; the products of the "plurilocular sporangia" are morphologically similar gametes; according to present views, the female gamete finally ceases its locomotion and usually fuses with an actively motile male gamete; the gametes of either sex may germinate without copulation.

Cold and temperate North Atlantic; Alaska; Mediterranean.

Beaufort, N. C.—Abundant throughout harbor, 5 to 15 cm. below low water, and on Bogue Beach, April, 1908; very abundant throughout harbor and on Fort Macon jetties, May, 1907.

This species is distinguished with difficulty from *E. confervoides*, with which it is often confused. It differs from the latter in the greater diameter of its branches and its usually more tapering "plurilocular sporangia." The sporangia of these two species seem, however, to intergrade. The illustration (fig. 8) shows about the average shape of the sporangia observed in *E. siliculosus* by the author. Some of these are very long and extended into a long, slender, pointed hair, while some are shorter, approaching closely to the more slender sporangia of *E. confervoides.*

3. **Ectocarpus confervoides** (Roth) Le Jolis. Fig. 9.

Ceramium confervoides, Roth, 1797, p. 151.
Ectocarpus confervoides, Le Jolis, 1863, p. 75.
Ectocarpus confervoides, Farlow, 1882, p. 71.
Ectocarpus confervoides, De Toni, 1895, p. 551.
P. B.-A. No. 871.

Fronds 2 to 50 cm. long, attached, deep brown; branches scattered, secund or alternate, not opposite; lower cells of the branches 18 to 40 mic. in diameter; "unilocular sporangia" oval or ellipsoidal, 23 to 30 mic. broad, 35 to 50 mic. long, sessile; "plurilocular sporangia" short subulate or fusoid, sessile or shortly pedicellate, 20 to 40 mic. broad, 60 to 400 mic. long, not tapering to a hair.

Cold and temperate North Atlantic and Pacific; Mediterranean.

Common in harbor and on rocks of Fort Macon jetties, Beaufort, N. C., January to April, 1909.

This species is distinguished with difficulty from *E. siliclulosus*, with which it is often confused. From this it differs in the smaller diameter of its branches and its less tapering "plurilocular sporangia." Authors have distinguished several varieties or forms, some perhaps agreeing in all respects with forms of *E. siliculosus.*

4. **Ectocarpus mitchellæ** Harvey. Fig. 10.

Ectocarpus mitchellæ, Harvey, 1852, p. 142, pl. 12 G.
Ectocarpus mitchellæ, Farlow, 1882, p. 72.
Ectocarpus mitchellæ, De Toni, 1895, p. 558.
P. B.-A. Nos. 321, 671, 1921.

Fronds 1.5 to 17 cm. long, yellow-greenish to dark brown, forming lax, feathery tufts; filaments slender, profusely branched; branches and branchlets alternate, ultimate ones approximate, all patent; cells of the branches 2 to 3 diameters long, those of the branchlets 1.5 diameters; "plurilocular sporangia" elliptical oblong or linear, very obtuse, sessile, divided into numerous cells, several together.

Warm and temperate North Atlantic and Pacific.

Abundant on other algæ, marine grasses, shells, etc., on shoals throughout harbor, on buoys, and on rocks of Fort Macon jetties, Beaufort, N. C., summer and autumn; Bogue Beach, March, 1909. Very abundant on marine grasses and rocks on shoals and jetties, Pamlico Sound, Ocracoke, N. C., August, 1907. Fruits throughout summer and autumn.

With the exception of *E. duchassaingianus*, collected in a single locality, this is the only determinable species of Ectocarpus that has been found at Beaufort in the summer and autumn.

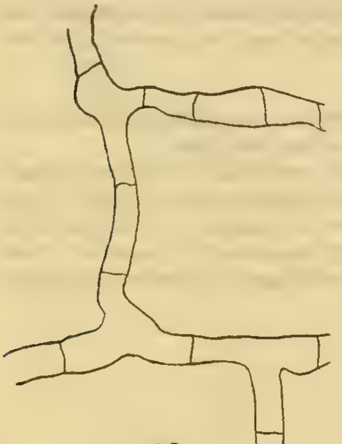
A small amount of Ectocarpus evidently belonging to another species than those described here (fig. 11), but insufficient for specific determination, was dredged from the coral reef offshore from Beaufort in August, 1914.

Genus 2. **Streblonema** Derbes and Solier.

Streblonema, Derbes and Solier, in Castagne, 1851, p. 100.

Frond filamentous, monosiphonous, composed of decumbent primary filaments living within the tissue of other algæ, and erect secondary filaments arising from these; secondary filaments sometimes lacking, the upright portion consisting of only sporangia and hairs; branches of the decumbent filaments usually free, not anastomosing; sporangia usually occurring singly, subsessile on the decumbent filaments or terminal or lateral on short or long upright filaments; "unilocular sporangia" subglobose, rather large; "plurilocular sporangia" various in form, sometimes conspicuously branched, consisting of one or, for the greater part, many rows of cells in the longitudinal direction; products of "plurilocular sporangia" not known.

About 20 species, in other algæ, North Atlantic and Mediterranean.



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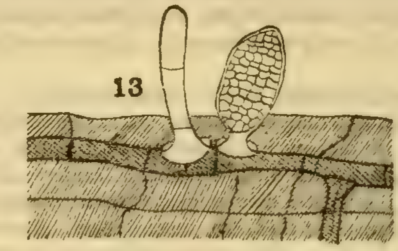

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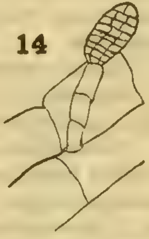

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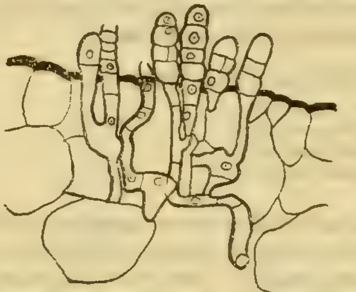

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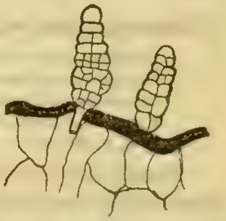

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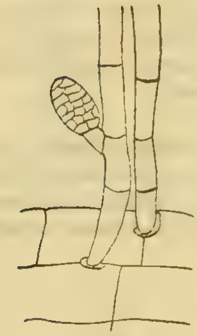

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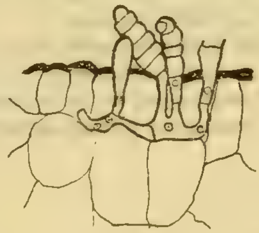

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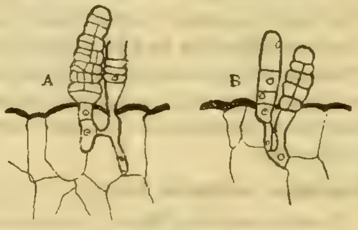

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Fig. 12.—*Streblonema solitarium*, internal filaments branched and anastomosed, × 277.

Fig. 13.—*Streblonema solitarium*, internal filament bearing hair and "plurilocular sporangium," × 277.

Fig. 14.—*Streblonema solitarium*, terminal "plurilocular sporangium," × 277.

Fig. 15.—*Streblonema solitarium*, long external filaments and lateral "plurilocular sporangium," × 277.

Fig. 16.—*Streblonema invisibile* in *Meristotheca duchassaingii*, internal filaments bearing "plurilocular sporangia" of various ages and one hair, × 206.

Fig. 17.—*Streblonema invisibile* in *Meristotheca duchassaingii*, internal filament bearing "plurilocular sporangia" of various ages, × 206.

Fig. 18.—*Streblonema invisibile* in *Meristotheca duchassaingii*, internal filament bearing "plurilocular sporangium" and hair, × 206.

Fig. 19.—*Streblonema invisibile*, "plurilocular sporangia," × 206.

KEY TO SPECIES.

Internal filaments 10 to 15 mic. wide, external filaments often long, plurilocular sporangia
ovoid or ovoid-globose, 18 to 35 mic. wide..........................1. *S. solitarium* (p. 441).
Internal filaments 5 to 8 mic. wide, external filaments short, plurilocular sporangia lanceolate,
obtuse, 11 to 17 mic. wide..2. *S. invisibile* (p. 441).

1. **Streblonema solitarium** (Sauvageau) De Toni. Figs. 12–15.

Ectocarpus solitarius, Sauvageau, 1892, p. 97, pl. 3, f. 24–27.
Streblonema solitarium, De Toni, 1895, p. 576.

Thallus mainly endophytic, filaments intercellular, 10 to 15 mic. wide, laterally and fairly profusely branched, occasionally anastomosing, giving off upright branches forming usually simple solitary hairs projecting about 0.1 to 1 mm. above the surface, cells 9 to 15 mic. wide, 2 to 4 diameters long; "plurilocular sporangia" terminal on short, upright filaments or lateral on the longer ones, ovoid or ovoid-globose, 25 to 105 by 14 to 45 mic.; "unilocular sporangia" unknown.

On *Dictyota dichotoma* on the Atlantic coast of France.

Fairly abundant on *Dictyota dichotoma* from the coral reef offshore from Beaufort, N. C., August, 1914.

The external filaments of this species are plainly evident under the microscope, and the internal filaments can be traced for long distances in the host. The upright branches reach the exterior through evident pores formed in the cell walls of the host. These pores are conspicuous on the surface of the Dictyota after the decay of the Streblonema filaments. At Beaufort the sporangia are usually borne on the ends of short filaments (fig. 14), but are sometimes lateral on long filaments (fig. 15), or borne on short stalks on the internal filaments (fig. 13); the internal filaments are branched fairly abundantly and seem to anastomose occasionally (figs. 12 and 13); the external filaments are usually simple, but sometimes branch. Although differing slightly from the published descriptions, there seems no doubt of the identity of this species.

This species is easily distinguished from the following by its larger size, its more luxuriant growth, the usually solitary paraphyses and sporangia, and the shape of the sporangia. It has not previously been recorded for North America.

2. **Streblonema invisibile** sp. nov. Figs. 16–19.

Thallus endophytic, filaments intercellular, usually 5 to 8 mic. wide, irregularly swollen here and there (in intercellular spaces?), variously and sparsely branched, traversing the host in all directions, giving off upright branches forming sporangia and short, simple hairs above the surface; "plurilocular sporangia" numerous, occurring in irregular patches, accompanied by a few hairs, lanceolate, obtuse, 25 to 55 by 11 to 17 mic., usually 40 to 45 by 14 to 17 mic.; "unilocular sporangia" unknown.

Thallo endophytico, filis intercellularibus, plerumque 5–8 mic. latis, hic illic inaequaliter tumidis (in spatiis intercellularibus?) varie et rare ramosis, passim hostem percurrentibus, ramos erectos sporangia et pilos breves et simplices externe formantes emittentibus; sporangiis plurilocularibus numerosis cum pilis paucis in locis inaequalibus, lanceolatis, obtusis, 25–55 x 11–17 mic., plerumque 40–45 x 14–17 mic.; sporangiis unilocularibus ignotis.

Abundant throughout the greater part of one tetrosporic specimen of *Meristotheca duchassaingii* J. Ag. collected on Bogue Beach, Beaufort, N. C., August 2, 1906.

A minute species, invisible to the naked eye, and even with the microscope scarcely visible except in section. Of the described species it seems to resemble most closely *Streblonema investiens* Thuret. From this it differs in having coarser, more irregular filaments with large, irregular swellings, confined below the surface of the host, the hairs projecting beyond the surface being very different from the projecting filaments of that species. Frequently a sporangium and a hair occur together as branches from a common filament.

This species is easily distinguished from the preceding by its smaller size, its less luxuriant growth, the occurrence of paraphyses and sporangia in clusters, and the shape of the sporangia.

The type and the slides from which the drawings were made have been deposited in the U. S. National Herbarium.

An undetermined species, apparently belonging to this genus, was abundant on several pieces of *Nitophyllum medium* collected on Bogue Beach in July and August, 1907, giving a brownish color to the host. The horizontal filaments branched irregularly, pursuing an irregular course among the cells of the Nitophyllum, from these short, vertical filaments, one to few celled, not visible to the naked eye, emerged to the surface. No fruit was observed, the specimens apparently being immature.

Genus 3. **Phæostroma** Kuckuck.

Phæostroma, Kuckuck, in Reinbold, 1893, p. 43.

Thallus composed of a small disk, usually monostromatic, consisting of radiating, branched, coalescent filaments, furnished with hairs arising by basal growth; both "unilocular" and "plurilocular" sporangia arising from the transformation of vegetative cells, rather prominent; "unilocular sporangia" globose or pear-shaped, opening by an apical cleft, "plurilocular sporangia" irregularly rounded or nodule-shaped.

Five species described, four of these from the northern shores of Europe. The genus has not previously been recorded from North America, except Greenland.

This genus, usually placed among the Encœliaceæ, has seemed to the author, from the vegetative structure and from the mode of formation of the reproductive organs, more nearly related to the Ectocarpaceæ, and has accordingly been placed there.

Phæostroma pusillum Howe and Hoyt. Pl. CXV, figs. 1-9.

Phæostroma pusillum, **Howe and Hoyt, 1916, p. 109, pl. 11, figs. 1-9.**

Thallus composed of horizontal branching filaments, forming irregular or somewhat disk-shaped patches, 0.3 to 0.8 mm. in diameter, closely attached to the surface of the host, usually consisting of a single, moderately compact layer with irregular margins; vegetative cells somewhat cylindrical or more often curved or of irregular diameter, mostly 10 to 16 mic. by 5 to 10 mic., usually 1.5 to 2 times as long as broad; hairs occasional, 8 to 10 mic. in diameter, showing at the base 4 to 6 short cells (5 to 10 mic. long); "unilocular" and "plurilocular sporangia" borne on separate individuals; "unilocular sporangia" either (1) scattered or aggregated, obovoid or somewhat globose, 8 to 16 mic. in diameter, sessile, or, (2) by subdivision and branching of the fundamental cell and by coalescence, forming elevated, submoriform sori 16 to 48 mic. in diameter, the ultimate sporangia then smaller, mostly 5 to 8 mic. in diameter, and often more angular; "plurilocular sporangia" scattered and solitary or forming loose clusters, ovoid, ellipsoid, or subconic, sessile, rather erect, 22 to 27 mic. by 15 to 18 mic.

Endemic.

Fairly abundant on *Dictyota dichotoma* and the creeping stolons of Campanularian hydroids on this, and occasionally on *Spyridia sp.*, from the coral reef offshore, Beaufort, N. C., August, 1914.

This species occurs on the Dictyota mixed with other filamentous species, but is easily distinguished from them by the descriptions and figures. It is not likely to be mistaken for any other species occurring in this region. It is not known elsewhere.

Family 2. ENCŒLIACEÆ (Kuetzing) Kjellman.

Frond extremely various in size and form, usually narrowed to a stipe below, attached by a rootlike disk or by rhizoids, usually simple, occasionally sparsely branched; structure parenchymatous; longitudinal growth intercalary, usually continuing longest in the lower part; both "unilocular" and "plurilocular" sporangia formed by the transformation of superficial cells or segments of these cells, external or immersed, occurring singly or grouped in sori, often accompanied by paraphyses; products of sporangia imperfectly known; in some cases isogametes, formed in "plurilocular sporangia," fuse to form a zygote; in other cases fusion of gametes apparently is not necessary for their development.

About 35 species, in all seas.

KEY TO GENERA.

Paraphyses lacking; sporangia, at least in the beginning, bound together into a tissuelike mass; frond band or leaf shaped..1. Petalonia (p. 443).
Paraphyses present or lacking; frond filiform, band shaped or intestine shaped. 2. Rosenvingea (p. 443).

Genus 1. **Petalonia** Derbes and Solier.

Petalonia, Derbes and Solier, 1850, p. 265.
Phyllitis, Farlow, 1882, p. 62.
Phyllitis, De Toni, 1895, p. 487.

Frond leaflike, without veins, usually band shaped, less often linear or filiform, tapering toward the base to a short, filiform stipe, occasionally fistulose; interior structure composed of larger cells intermixed with slender, segmented filaments, outer layer composed of smaller cells; sometimes hollow; paraphyses lacking; fertile regions at first as sori, then occupying nearly the entire surface of the frond; sporangia external, bound together, at least at first, into a tissuelike mass; "plurilocular sporangia" subcylindrical; "unilocular sporangia" insufficiently known.

Three species, in cold and temperate seas.

Petalonia fascia (Mueller) Küntze. Pl. LXXXVI, fig. 1.

Fucus fascia, Mueller, in Flora Danica, pl. 768.
Laminaria fascia, Harvey, 1852, p. 91.
Phyllitis fascia, Farlow, 1882, p. 62.
Phyllitis fascia, De Toni, 1895, p. 487.
Petalonia fascia, Küntze, 1898, p. 419.
A. A. B. Ex. No. 199 (*Phyllitis fascia*).
P. B.-A. Nos. 276, 736, 1131 (*Phyllitis fascia*), No. 1082 (*Petalonia zosterifolia*).

Frond extremely various in size and form, up to 30 cm. tall, 1 to 55 mm. broad, tapering cuneately below into a stipe springing from a shieldlike attachment, simple or branched.

Cold and temperate seas generally.

Abundant on rocks of Fort Macon and Shackleford jetties, less abundant in harbor, Beaufort, N. C., December to April, 1908 and 1909.

This species was not collected in November and seems to disappear entirely by May.

Genus 2. **Rosenvingea** Börgesen.

Rosenvingea, Börgesen, 1914, p. 178 (22).

Frond tubular, cylindrical, or slightly compressed, attached by a rootlike disk, branched, branches scattered or pseudodichotomous; growth intercalary by division of the cells of the entire frond; wall composed of 3 to 4 layers of cells, external ones small, becoming larger toward the cavity, peripheral cells containing single, disk-shaped chromatophores; hairs single or many aggregated, scattered over the entire frond, occurring either in the sori or on sterile portions of the frond; "plurilocular sporangia" subcylindrical or club-shaped, arising from the division of the cortical cells, occurring in sori forming very irregular spots scattered over the entire surface of the frond.

Four species in warm and temperate seas.

Rosenvingea orientalis (J. Agardh) Börgesen. Pl. LXXXVI, fig. 2.

Asperococcus orientalis, J. Agardh, 1848, p. 78.
Asperococcus orientalis, De Toni, 1895, p. 495.
Rosenvingea orientalis, Börgesen, 1914, p. 182 (26).
P. B.-A. No. 1640 (*Asperococcus orientalis*).

Frond tubular, light yellow-brown; 10 to 40 cm. long, 1 to 2 mm. diameter, dichotomous or vaguely branched, here and there constricted and twisted; branches usually tapering at base and apex, repeatedly dichotomous.

Warm waters of Atlantic, Pacific, and Indian Oceans.

Beaufort, N. C.: Abundant September and October, 1905, Bogue Beach; occasional in later years; fairly abundant attached to shells and marine grasses between jetties at Fort Macon, occasional on jetties, August and September, 1906 and 1907; occasional on sea buoy and Shackleford jetty, 1906 and 1907. Wrightsville Beach, N. C.; Fairly abundant in sound near inlet, August and September, 1909; abundant in almost pure masses on beach, August, 1909.

This species was first observed at Beaufort on the beach in 1905, it appeared in the harbor in 1906, was fairly abundant there for two summers, and then seemed to disappear, not being recorded for the region in 1908 or 1909.

It reaches its northern known limit at Beaufort.

Family 3. ELACHISTEACEÆ Kjellman.

Elachistaceæ, De Toni, 1895, p. 436.

Frond minute, sometimes almost microscopic, epiphytic, forming a pad or tuft consisting of a horizontal and an erect portion; horizontal portion consisting of loose or more or less closely adherent, branched filaments, upright portion consisting of filaments, usually branched below, simple above, loosely grouped, or more or less densely compacted, sometimes forming an almost parenchymatous structure below; filaments monosiphonous or polysiphonous, with longitudinal growth basal or lasting longest at the base; "unilocular" and "plurilocular" sporangia formed in the place of assimilating filaments, or by the transformation of single assimilating cells, or of offshoots from these cells.

About 20 species, in all seas, especially in the North Atlantic Ocean.

Genus **Elachistea** Duby.

Elachistea, Duby, 1832, p. 339 (19).
Elachista, De Toni, 1895, p. 439.

Frond forming small pads or tufts showing horizontal and erect portions; horizontal portion composed of monosiphonous branched filaments loosely or closely aggregated; from this arises the erect portion, usually consisting of a basal layer and erect filaments, the basal layer composed of branched, mostly colorless, monosiphonous filaments more or less densely compacted, sometimes forming an almost parenchymatous structure, erect filaments monosiphonous, simple or sparingly branched below, moderately or greatly elongated, richly colored; "unilocular sporangia" pear shaped, "plurilocular sporangia" filiform, usually consisting of a single row of cells, occasionally divided to form two rows of cells, both kinds of sporangia arising from the basal layer.

About 15 species, widely distributed, but most abundant in the North Atlantic Ocean.

Elachistea stellulata (Harvey) Griffiths. Figs. 20 and 21.

Conferva stellulata, Harvey, 1841, p. 132.
Elachista stellulata, Griffiths, in Areschoug, 1843, p. 261.
Elachista stellulata, De Toni, 1895, p. 439.

Thallus consisting of extensive endophytic filaments from which arise, here and there, external, hemispherical tufts of erect filaments and sporangia; internal filaments irregularly and profusely branched, frequently anastomosing, segmented, irregular in form and size, erect filaments and sporangia arising from a poorly developed basal layer, erect filaments 0.3 to 0.8 mm. long, 5 to 10 mic. wide, "unilocular sporangia" obovate or pear shaped, about 25 by 10 mic., "plurilocular sporangia" usually long, cylindrical, sometimes club shaped, obtuse, 30 to 50 by 5 to 10 mic.

On *Dictyota dichotoma*, England.

Fairly abundant on *Dictyota dichotoma* dredged from the coral reef offshore, Beaufort, N. C., August, 1914.

This species is visible as minute dots under a strong lens and is easily recognized under the microscope by the external hemispherical tufts of paraphyses and sporangia arising from widely scattered internal filaments. The internal filaments may be traced for long distances through the host. In European specimens the "unilocular sporangia" are the more abundant, but in the Beaufort plants these are very rare, and the "plurilocular sporangia" are abundant.

This species has not previously been recorded for North America.

Family 4. CHORDARIACEÆ (Agardh) Zanardini.

Frond convex-discoid or pulvinate, hemispherical or globose and finally hollow, or filiform and regularly branched, more or less slippery, sometimes almost gelatinous; segmented hairs always present; longitudinal growth terminal or subterminal; surface covered by short assimilating filaments; "plurilocular sporangia" formed either by the transformation of some segments of these filaments, or (like the "unilocular sporangia") in the place of filaments, or arising laterally on the filaments.

About 65 species, in all seas, especially in North Atlantic.

KEY TO GENERA.

a. Frond forming a horizontally expanded, parenchymatous, monostromatic disk with upright assimilating filaments.......................1. Myrionema (p. 445).
aa. Frond forming a more or less large, upright body.......................*b*.
  b. Longitudinal growth by transverse division of subterminal cells of the axial filament, assimilating filaments secondary; axial body of the frond composed of series of cells solidly joined together; filiform, branched.......................2. Castagnea (p. 446).
  bb. Longitudinal growth by transverse division of the upper segments of free apical filaments, the upper divisions finally changed into assimilating filaments; axial body of the fertile frond composed of rows of cellular filaments many times furcate, more or less loosely connected, anastomosing; hemispherical to subglobose.......................3. Leathesia (p. 447).

Genus 1. Myrionema Greville.

Myrionema, Greville, 1827, vol. 5, pl. 300.

Thallus consisting of a very minute, horizontally expanded, round, or oblong disk composed of a single layer of rather closely packed cells, from which arise numerous erect, monosiphonous, assimilating filaments; sporangia arising from the basal disk on more or less elongated stalks; "unilocular sporangia" ellipsoidal or pear shaped, "plurilocular sporangia" silique shaped, at least in the lower part, consisting of several series of cells, usually borne on different plants, sometimes on the same plant.

Two to four species, on other plants, mostly in the North Atlantic Ocean and the Mediterranean Sea.

Myrionema strangulans Greville.

Myrionema strangulans, Greville, 1827, vol. 5, pl. 300.
Myrionema strangulans, Harvey, 1852, p. 132.
Myrionema vulgare, Farlow, 1882, p. 79.
Myrionema strangulans, De Toni, 1895, p. 399.
P. B.-A. Nos. 1795, 280 (*M. Ledanckerii*), 32, 924, 1689 (*M. vulgare*).

Thallus forming minute spots more or less expanded over other plants, basal layer composed of elongated, segmented filaments almost joined into a membrane, with cells about 1.5 diameters long, vertical filaments numerous, densely crowded, club shaped, with short cells, intermixed with hyaline, confervoid filaments with elongated cells; "unilocular sporangia" obovoid, about 30 to 40 mic. long, 19 to 27 mic. wide, arising from the basal layer, borne on short stalks or almost sessile; "plurilocular sporangia" unknown.

North Atlantic and Mediterranean.

Fairly abundant on *Petalonia fascia*, from Fort Macon jetty, April, 1908 and 1909, and fairly abundant on *Nitophyllum medium*, Bogue Beach, summer and autumn, Beaufort, N. C.

This species was not found on Petalonia in December, 1908, nor January, 1909, was barely evident in February and March, and reached full development in April.

The specimens on Nitophyllum have not been observed in a mature condition, but seem to agree closely with this species.

This is the only species forming a disk on the surface of other plants which has been observed here. As, however, several members of the Ectocarpaceæ have this form and may be found in this region, determinations should not be based on this character alone.

Genus 2. **Castagnea** Derbes and Solier.

Castagnea, Derbes and Solier, 1856, p. 56.

Frond cylindrical, composed of an axis and peripheral radiating filaments with a stiffening, inconspicuous jelly; axis solid or tubular, composed of cylindrical, oblong cells joined into filaments tightly bound together by mucilage, forming almost a parenchymatous structure; the peripheral filaments of rotund cells, going out from the axis, approximate and fasciculate, the sterile branches rather simple, enfolding the sporangia, the fertile branches thrusting out externally shorter subsecund branches below their apices; "plurilocular sporangia" formed from the transformation of the upper (outer) segments of the assimilating filaments; "unilocular sporangia" produced as lateral offshoots from the base of assimilating filaments.

About six species, North Atlantic Ocean, Mediterranean.

The proper name for this genus is a matter of considerable doubt. But, as the author has had no opportunity for obtaining facts bearing on the question, it has seemed proper to follow the usage that is most current, even though further study should show that this name must be replaced by an earlier one.

Castagnea zosteræ (Mohr) Thuret. Pl. LXXXVII, fig. 1.

Rivularia zosteræ, Mohr, 1810, p. 367.
Castagnea zosteræ, Thuret, in Le Jolis, 1863, p. 85.
Castagnea zosteræ, Börgesen, 1914, p. 184 (28), f. 144-145.
(Not *Castagnea zosteræ*, Farlow, 1882, p. 86, pl. 7, f. 2.)
(Not A. A. B. Ex. No. 162.)
P. B.-A. Nos. 481, 1879 (*Castagnea mediterranea*).

Frond filiform, cylindrical, somewhat inflated, attached by a small basal disk, 7 to 20 cm. tall; branching sparse or fairly abundant, alternate and irregular, branches arising almost horizontally, short or elongated and ascending, sometimes irregularly divided at apices, tapering toward the base and apex; structure tubular, the central cavity being bordered by longitudinal filaments tightly bound together with mucilage, nearly all the cells of the outer filaments of this central tube giving off several short, lateral, assimilating filaments and an occasional hair, growth of the longitudinal filaments intercalary; "unilocular sporangia" oblong-ovate, arising from near the base of the assimilating filaments, "plurilocular sporangia" conical or irregular in shape, sometimes branched, arising from the apices of the assimilating filaments, "unilocular" and "plurilocular" sporangia occurring on the same plants; texture soft and rather gelatinous, the surface rough like the pile of velvet; color dark brown.

Atlantic coast of North America and Europe.

Fairly abundant on Bogue Beach, Beaufort, N. C., April 20, 1908; not found any other day.

The identity of this species has been, and still is, the source of much confusion. Harvey (1852) gives a species under the name *Mesogloia zosteræ* Aresch; Farlow (1882) uses the name *Castagnea zosteræ* (Mohr) Thur., giving as synonyms, among others, *Myriocladia zosteræ* Ag. and *Mesogloia zosteræ* Aresch.; De Toni (1895) does not give *Castagnea zosteræ*, but recognizes two species (1) *Myriocladia zosteræ* J. Ag., giving as a synonym, among others, *Mesogloia zosteræ* Aresch., Exs. No. 67, Tab. VIII, f. 1, *a* and *b*, and (2) *Eudesme virescens* (Carm.) J. Ag., giving as synonyms *Mesogloia zosteræ* Aresch., Alg. Scand. exs. No. 67, *Linckia zosteræ* Lyngb. and *Aegira zosteræ* Fries. Further study is needed to determine how many species are included here and to what genera these should be referred.

The species considered here seems to be the same as that discussed by Börgesen (1914), but it may, perhaps, be questioned whether it is the same as *Rivularia zosteræ* Mohr or *Castagnea zosteræ* Thuret. Both the Beaufort and the Bermuda plants are more branched than the more northern ones called by this name, and seem to belong to a different species.

The single occurrence of this species on the beach makes it probable that these plants did not grow in this locality, but were brought here from some other region. Since, however, it probably occurs both north and south of this place, it may be expected to establish itself here at any time.

Genus 3. **Leathesia** Gray.

Leathesia, Gray, 1821, p. 301.

Frond small, at first globose and solid, at length irregularly lobate and hollow, gelatinous-fleshy; axis short, composed of oblong cells joined into decompound-forked filaments radiating from a central point; peripheral assimilating filaments short, going out from the outermost smaller cells, enwrapped in mucous, simple, clavate, short, moniliform-segmented; longitudinal growth by transverse division of the upper segments of free apical filaments, the upper divisions finally changed into assimilating filaments; "unilocular sporangia" ellipsoid or pear shaped; "plurilocular sporangia" linear, composed of a single longitudinal series of cells; both kinds occurring at the base of peripheral filaments.

Five to six species, in cold and temperate seas.

Leathesia difformis (Linnæus) Areschoug. Pl. LXXXVIII, figs. 1 and 2.

Tremella difformis, Linnæus, 1755, p. 429.
Leathesia difformis, Areschoug, 1847, p. 376, pl. 9 B.
Leathesia tuberiformis, Harvey, 1852, p. 129.
Leathesia difformis, Farlow, 1882, p. 82, pl. 5, f. 1.
Leathesia difformis, De Toni, 1895, p. 422.
P. B.-A. Nos. 130, 829.

Frond subglobose, variously lobate, variable in size, about 1 to 5 cm. in diameter, olivaceous brown; at first solid, soon becoming hollow by the disintegration of the cells of the central axis; peripheral filaments clavate, the terminal cell enlarged; sporangia about 35 by 17 mic.

Cold and temperate North Atlantic and Pacific.

Abundant on other algæ and on rocks of Fort Macon jetties, Beaufort, N. C., April, 1908, March and April, 1909.

This is the most southern station reported for the species, although it may be found slightly farther south in the winter or spring. The species seems to make a short stay at Beaufort, not being found there in May, 1907, and being collected in only the two months noted during the winter and spring of 1908–9. The Beaufort specimens were small, having a diameter of 1 to 2 cm.

Family 5. STILOPHORACEÆ (Nægeli) De Toni and Levi.

Frond attached by a rootlike disk, filiform, more or less branched, composed of an axial bundle of segmented filaments increasing in length by the division of subterminal cells, and a parenchymatous, few-layered, cortical tissue clothing the axis; this cortical tissue arising from the lower cells of the segmented, subclaviform filaments springing from the axial bundle below its apex; frond solid when young, often becoming hollow with age, and traversed by branches of the axial filaments; assimilating filaments present; sporangia of both kinds formed as lateral branches from the base of short, simple, or branched filaments arising from superficial cells; "unilocular sporangia" obovate or club shaped; "plurilocular sporangia" linear, consisting of a single longitudinal row of cells.

Five to six species in North Atlantic and Mediterranean.

Genus **Stilophora** J. Agardh.

Stilophora, J. Agardh, 1836, p. 16.

Frond filiform, branched, firm, cartilaginous, finally hollow in the lower portions; growth in length apical; central axis composed of a few (usually four to five) series of cells; apex surrounded by tufts of filaments, arising laterally; peripheral assimilating filaments segmented, differing among themselves in form, either covering the surface of the frond or occurring in groups here and there; "plurilocular sporangia" uniformly distributed or grouped in more or less definite sori.

Four to five species in North Atlantic and Mediterranean.

Stilophora rhizodes (Ehrhart MS.) J. Agardh. Pl. LXXXVII, fig. 2.

Conferva rhizodes, Ehrhart MS., in Turner, 1819, vol. 4, p. 91.
Fucus rhizodes, Turner, 1819, vol. 4, p. 91.
Stilophora rhizodes, J. Agardh, 1841, p. 6.
Stilophora rhizodes, Harvey, 1852, p. 112, pl. 9 B.
Stilophora rhizodes, Farlow, 1882, p. 90, pl. 5, f. 4, pl. 6, f. 2
Stilophora rhizodes, De Toni, 1895, p. 390.
P. B.-A. No. 83.

Frond much branched, usually regularly dichotomous with more or less abundant minute lateral branches, 8 to 30 cm. long, about 1 mm. diameter below, yellowish when living, brownish when dry; branches elongated, plainly tapering toward the apices; sori separate, scattered among the more or less extensive sterile portions of the cortex, "unilocular" and "plurilocular" sporangia formed on different individuals.

Temperate North Atlantic; Mediterranean.

Beaufort, N. C.: Very abundant in Mullet Pond, on Shackleford Banks, May, 1907, April, 1908, loose or attached, lying in loose masses on the bottom; few specimens in tide pool in northwest corner of Town Marsh, May, 1907; one specimen in harbor north of laboratory, April, 1908.

Specimens from different localities vary greatly in more or less conspicuous tufts of peripheral filaments and in abundance of minute branches on various portions of the thallus. The Beaufort specimens have tufts of peripheral filaments large and conspicuous and few minute branches. In habit it is between the typical form and forma contorta Holden, occurring in masses with branches slightly contorted and intertwined. At Beaufort it occurred, with the exception of one specimen, in tide pools that were considerably warmer than the water in the harbor, but were very muddy. This is the most southern station reported for the species on our shores, but it may be found farther south in the winter or spring.

Family 6. SPOROCHNACEÆ (Reichenbach) Hauck.

Thallus usually filiform, sometimes narrow-band shaped, parenchymatous except at apices, where it is composed of tufts of free filaments; branching lateral, profuse, the branches in some cases differentiated into long and short ones; longitudinal growth trichothallic by a group of subterminal cells; only "unilocular sporangia" known, these are obovate, ellipsoid, or ellipsoid-cylindrical, produced as lateral outgrowths of special short, simple, or branched filaments arising from superficial cells; sporangiferous filaments occurring in sori scattered over the frond or confined to special regions.

About 20 species in warm and temperate seas, especially in the Australian region.

Genus **Sporochnus** Agardh.

Sporochnus, Agardh, 1820, p. 147.

Frond filiform, solid, regularly branched on all sides, usually having sharply distinct long and short branches, apices crowned with a tuft of free filaments; sporangia produced as lateral outgrowths uniformly distributed on short, more or less branched filaments with club-shaped branches and round pear-shaped end cells; sporangiferous filaments occurring in sori surrounding the short branches immediately below the apices; fertile portions of these branches cylindrical, club shaped, ellipsoidal, or almost globose.

About 14 species, mostly in Australian region; 3 in Europe.

Sporochnus pedunculatus (Hudson) Agardh. Pl. LXXXVIII, fig. 3.

Fucus pedunculatus, Hudson, 1762, p. 587.
Sporochnus pedunculatus, Agardh, 1820, p. 149.
Sporochnus pedunculatus, De Toni, 1895, p. 380.

Frond filiform, arising from a very minute, discoid, rootlike callus, greenish to olive brown, up to 40 cm. tall; densely pinnate, long branches rather simple, alternate, 1 to 20 cm. long; short branches numerous on the long branches, occasional on the main axis, usually 1 to 2 mm. long or less, sometimes up to 5 mm. long, fertile portions at first subsessile and subglobose, then pedicillate and more or less elongated, obovate-ellipsoid; sporangia about 30 to 40 by 10 to 15 mic.

Atlantic from Scandinavia and England to northern Africa; Mediterranean.

Beaufort, N. C.: One specimen, Bogue Beach, August, 1907; few fragments dredged from the coral reef offshore, August, 1914.

The large specimen mentioned differs from most English specimens of the species in that it is coarser, has the short branches more scattered with longer peduncles, and the fertile portions of these branches ending more abruptly than in the English specimens, but the English specimens are themselves variable in these respects and some of them closely approach the Beaufort plant. This species has not previously been recorded from America, the specimens from Bermuda referred in the Challenger report to *S. pedunculatus* probably being another species. *S. bolleanus* Mont., which occurs in Bermuda, differs from the Beaufort specimen in being coarser and having longer peduncles, those of *S. bolleanus* being 2 to 6 times those of the Beaufort specimen, 0.5 to 1.5 times the length of the fertile portion of the branch.

The large specimen collected at Beaufort is 16.5 cm. long and seems complete, except that it lacks its attaching base, its long branches are 1 to 4 cm. long, it is in good condition, is fruiting abundantly, and when found seemed fresh and vigorous. It is probable that this grew on the coral reef offshore from Beaufort.

Order 2. **Cyclosporeæ** Areschoug.

Cyclosporinæ, De Toni, 1895, p. 3.

Frond often of striking size, various in form, branching, and structure, usually on rocks, less often epiphytic, with or without vesicles (floats, air bladders); usually bearing on the surface tufts of hairs arising from the interior of sunken, flask-shaped cavities (cryptostomata); no asexual propagation; sexual reproduction by nonmotile eggs and biciliate motile sperms; sexual organs (oogonia and antheridia) accompanied by paraphyses, formed within sunken, subspherical, hermaphroditic or unisexual conceptacles, communicating with the exterior by a narrow canal, usually on more or less specialized portions of the thallus; oogonia spherical or ellipsoidal, occurring singly on a short stalk, producing 1, 2, 4, or 8 relatively large, nonmotile eggs; antheridia numerous, occurring as branches on more or less branched filaments, producing numerous small, biciliate, motile sperms; eggs and sperms discharged through the neck of the conceptacle into the water where fertilization occurs.

Family FUCACEÆ De Toni.

Characters of the order.

About 300 species, mostly in salt water, some in brackish water, throughout the world, especially in Australian region.

KEY TO GENERA.

Frond flat, band shaped, dichotomously branched in one plane, furnished with a midrib .... 1. Fucus (p. 450).

Frond distinctly differentiated into stem and leaflike portions, laterally branched, floats developed as special organs...2. Sargassum (p. 451).

Genus 1. **Fucus** (Tournefort) Linnæus.

Fucus, Linnæus, 1737, p. 326 (in part).

Frond flat, band shaped, repeatedly dichotomously branched in one plane, furnished with a more or less conspicuous midrib, attached by a basal disk; vesicles present or absent, formed from swollen portions of the frond, often in pairs on each side of the midrib; cryptostomata more or less conspicuous here and there over the frond, bearing tufts of paraphyses; apical cell three-sided in young stages, soon becoming four-sided; receptacles formed from the more or less swollen apices; unisexual or hermaphroditic; oogonia producing eight eggs, accompanied by numerous paraphyses; antheridia ellipsoidal, numerous, occurring as lateral branches of richly branched filaments, producing numerous sperms, accompanied by paraphyses; eggs spherical, relatively large, nonmotile; sperms small, pear shaped, biciliate, actively motile.

About 16 species, in cold and temperate seas.

Fucus vesiculosus Linnæus. Pl. LXXXIX.

Fucus vesiculosus, Linnæus, 1753, p. 1158.
Fucus vesiculosus, Harvey, 1852, p. 71.
Fucus vesiculosus, Farlow, 1882, p. 100, pl. 9.
Fucus vesiculosus, De Toni, 1895, p. 206.
A. A.B. Ex. No. 109.
P. B.-A. No. 577.

Frond dark brown or black, coriaceous, band shaped, variable in form and size, 2.5 cm. to 1 m. long, 1 to 25 mm. wide; repeatedly and regularly dichotomous; tapering below to a distinct stipe; furnished with an evident midrib; cryptostomata more or less conspicuous; vesicles usually present, sometimes lacking, variable in form, size, and arrangement, usually occurring in pairs, one on each side of the midrib; receptacles forming swollen portions at the tips of the branches, more or less conspicuous, variable in size and form, somewhat flattened, turgid; antheridia and oogonia produced on different plants.

North Atlantic and Pacific Oceans.

Beaufort, N. C.: Abundant on innermost jetty, and occasional elsewhere at Fort Macon from low water up to 60 cm. above low-tide line, fairly abundant in harbor along shores, occasionally fairly abundant on Bogue Beach.

This is the southern known limit of the species and of the genus on our coast.

The species is variable in size and form, in the presence or absence of vesicles and the abundance and shape of these when they are present, in the conspicuousness of the cryptostomata, and in the size, shape, and conspicuousness of the receptacles. The vesicles may vary from numerous short, round ones, crowded together in places so that they resemble a double chain of beads, to few long, scattered ones, or they may be confluent, forming large, bladderlike structures, or may be lacking. The receptacles may be lacking (in sterile specimens), or may be small, or may form large, swollen portions at the apices, or may extend some distance from apices, they may be long and narrow or short and broad, their apices may be acute or obtuse. The Beaufort specimens are 4 to 5 mm. wide (at the vesicles up to 9 mm. wide) and 10 to 30 cm. long; the cryptostomata are inconspicuous, the receptacles are only slightly swollen and extend when young 3 to 6 mm., when mature 1 to 2.5 cm. from the apices, they are scarcely wider than sterile portions of the frond; their apices are acute. At Beaufort the plants are sterile during the spring and summer, commencing to form their receptacles in August and maturing these by November. Plants collected from November to January have mature fruits, those collected from April to August are entirely sterile. The species was not collected in February or March, 1909, but was probably present. In May, 1907, numerous small plants 2 to 3 cm. long were found, in addition to large ones up to 30 cm. long; all were sterile.

Genus 2. **Sargassum** Agardh.

Sargassum, Agardh, 1820, p. 1.

Frond attached by a basal disk or free floating, consisting of evident stem and leaf-like portions, bearing, in addition to these, vesicles and receptacles as separate organs; main axis short; branching lateral, alternate, decompound; stem terete, flattened, or angular; leaves variously shaped, sometimes branched, consisting of a flattened lamina usually on a short petiole, provided with a more or less conspicuous midrib traversing the entire leaf or extending through only the lower half, lamina sometimes reduced so that the leaf consists of little more than the midrib, margins smooth, serrate, or dentate; vesicles spherical, ellipsoidal, or obovate, sometimes flattened, occurring singly, formed from transformed leaves or parts of leaves (the transformation taking place at a young stage), borne on short stalks, often with flat, unaltered portions of the leaf remaining along the stalk and at the apex of the vesicle, the remnant at the apex often reduced to a spinelike tip; cryptostomata present only on the leaves, sometimes lacking; receptacles simple or branched, terete, flattened, or angular, often axillary; conceptacles usually spherical, communicating with the exterior by a narrow canal, hermaphroditic; oogonia accompanied by a few simple or branched paraphyses, producing only one egg; antheridia rotund on racemosely branched filaments.

About 160 species, grouped in five subgenera containing numerous sections, in warm and temperate seas throughout the world, especially in Australian region.

Some of the species are easily distinguishable, but most of them are separated by slight, inconspicuous characters. With the large number of species separated by slight differences, it is difficult to give an idea of these differences by descriptions. Determinations here, more than in most genera, can be made only by comparison with authentic specimens.

Seventeen species are reported for North America, 15 being found on the eastern coast. Most of these are southern, only one, *S. filipendula*, extending to the north, with one other, *S. natans*, often washed ashore. In the region studied, attached forms are apt to be *S. filipendula*, and floating ones are apt to be *S. filipendula* var. *montagnei* if fertile, or *S. natans* if sterile, although an occasional representative of other species may be found washed ashore.

While the extreme forms of these two species are easily distinguished, intermediate forms approach each other. Some specimens referred to *S. natans* by various workers bear a closer resemblance to *S. filipendula* var. *montagnei*. Such specimens will give much trouble to those who may try to name them.

Observations of Tahara and others show that in some species of this genus eggs are produced periodically at intervals of five to eleven days, apparently bearing no definite relation to the tides.

KEY TO SPECIES.

Cryptostomata usually lacking, leaf margins conspicuously serrate, branching rather irregular, usually sterile .... 1. *S. natans* (p. 452).

Cryptostomata present, usually conspicuous, leaf margins often not conspicuously serrate, branching fairly regular, usually fruiting .... 2. *S. filipendula* (p. 452).

1. **Sargassum natans** (Linnæus) Meyen. Pl. XC, fig. 1.

Fucus natans, Linnæus, 1753, Tom. 2, p. 1160.
Fucus bacciferus, Turner, 1802, vol. 1, p. 55.
Sargassum bacciferum, Agardh, 1820, p. 6.
Sargassum natans, Meyen, 1838, p. 185.
Sargassum bacciferum, Harvey, 1852, p. 59.
Sargassum bacciferum, Farlow, 1882, p. 103.
Sargassum bacciferum, De Toni, 1895, p. 82.
Sargassum natans, Börgesen, 1914a, p. 7.
A. A. B. Ex. No. 105 (in part).
P. B.-A. Nos. 382, 2180.

Fronds 15 to 45 cm. long, coriaceous, shining chestnut brown; stems terete, many times decompound; leaves lanceolate-linear, on a rather long petiole, occasionally forked, 4 to 10 cm. long, 1 to 7 mm. broad, acutely serrate, midrib distinct, cryptostomata usually lacking; vesicles spherical, on terete petioles whose length about equals that of the vesicles, usually provided with a spinelike tip; receptacles axillary, forked, cymose, cylindrical, verrucose; usually sterile.

Floating in North Atlantic, especially near the Gulf Stream. No specimen surely referable to this species is known attached.

Occasionally abundant in summer on Bogue Beach, Beaufort, N. C., not observed at other seasons. Fairly abundant on beaches at Southport, N. C., Georgetown, S. C., and Isle of Palms in the harbor of Charleston, S. C., July and August, 1909.

Forma **angustum** (Collins) comb. nov.

Sargassum bacciferum f. *angustum*, Collins, in Collins, Holden and Setchell, Phycotheca Boreali-Americana, No. 833, 1901.
A. A. B. Ex. No. 105 (in part).
P. B.-A. No. 833.

Leaves long, narrow, 2 to 6 cm. long, 1 mm. or less wide, in extreme cases consisting of little more than the midrib, conspicuously serrate, cryptostomata lacking; vesicles spherical, sometimes tapering very slightly at base, sometimes provided with a spinelike tip, petiole 1 to 3 times length of vesicle; sterile.

Floating in North Atlantic, with the species.

Occasionally abundant in summer, Bogue Beach, Beaufort, N. C., not observed at other seasons; probably in other localities also.

2. **Sargassum filipendula** Agardh. Pl. XC, fig. 2.

Sargassum filipendula, Agardh, 1824, p. 300.
Sargassum filipendula, Harvey, 1852, p. 61.
Sargassum vulgare, Farlow, 1882, p. 103.
Sargassum filipendula, De Toni, 1895, p. 106.
A. A. B. Ex. No. 101 (*S. vulgare*).
P. B.-A. Fasc. D. No. XCVII, Fasc. E. No. CXIX (*S. vulgare*).

Fronds 30 to 150 cm. long, yellowish-brown; stems terete or slightly flattened decompound, smooth; leaves linear-lanceolate or narrow linear, on a short petiole, sometimes forked, 1 to 5 cm. long, 1.5 to 12 mm. broad, larger and broader below, smaller and narrower above, acutely serrate or the upper narrower ones subentire, midrib distinct, cryptostomata more or less conspicuous, usually occurring singly, serially arranged on both sides of the midrib; vesicles spherical, on flattened petioles usually longer than the vesicles, usually provided with a spinelike tip; receptacles cylindrical, verrucose, paniculate on an elongated axillary branch, the lower ones pedicillate, rather simple, the upper ones confluent.

Warm and temperate North Atlantic.

Beaufort, N. C.: Abundant in harbor and on Fort Macon and Shackleford jetties throughout the year, from low-water line to 1 m. below low water; abundant on coral reef offshore at depth of 24 to 25.5 m., May, 1907, August, 1914, and August, 1915.

Most of the specimens from our coast which have been referred to *S. vulgare* Ag. belong to this species or to one of its forms, but specimens of the true *S. vulgare* are known from the extreme south, Key West, Fla., Mexico, and West Indies. The species differs from *S. vulgare* in having narrower leaves, longer petioles of vesicles, and more racemose branching of receptacles; many specimens have also less conspicuously serrate leaf margins, and the leaves less rigid and leathery. With its various forms the species shows much variation in the shape and size of leaves, the amount of serration, and the abundance of cryptostomata.

The Beaufort specimens fit the description of the species and resemble specimens from other localities referred to this species except that in the Beaufort plants the cryptostomata are inconspicuous and sometimes lacking. They have leaves broader and less serrate than in the type, these being as short and broad as in f. *contractum* J. Ag. with their margins almost as little serrate as in var. *montagnei* Collins and Hervey. In the Beaufort plants the leaves are lanceolate 1.5 to 3.5 cm. long, 3 to 7 mm. broad; the vesicles are rounded, tapering slightly at the base and sometimes very slightly at the apex, in the latter case bearing a short spinelike tip, their petioles are 1.5 to 3 times the length of the vesicle. The plants from the coral reef have large lanceolate leaves at the base, 8 to 8.5 cm. long, 1 to 1.3 cm. broad, long, narrow linear leaves at the apex, 3.5 to 5.5 cm. long, 3 to 5 mm. broad, approaching in appearance the leaves of var. *montagnei;* the serrations are inconspicuous on both kinds of leaves.

Var. **montagnei** (Bailey) Collins and Hervey.

Sargassum montagnei, Bailey, in Harvey, 1852, p. 58, pl. 1 A.
Sargassum vulgare var. *montagnei*, Farlow, 1882, p. 103.
Sargassum filipendula f. *subedentatum*, J. Agardh, 1889, p. 120.
Sargassum filipendula f. *subedentatum*, De Toni, 1895, p. 107.
Sargassum filipendula var. *montagnei*, Collins and Hervey, 1917, p. 83.
P. B.-A. No. 2176.

Leaves long, narrow, linear, 2 to 7.5 cm. long, 1 to 5 mm. wide, serrations almost or entirely lacking, the margins usually being smooth and wavy, cryptostomata often abundant and conspicuous; vesicles rounded or oblong on petioles 1 to 3 times the length of the vesicle; receptacles cylindrical, branched, cymose-racemose.

Atlantic shores of North America.

Abundant on Bogue Beach, Beaufort, N. C., summer and autumn; abundant in trawl offshore from Brown's Inlet, south of Beaufort, N. C., July, 1915.

The specimens belonging to this form often differ considerably from the species in appearance, but at Beaufort are fairly uniform among themselves. It is not known from what locality these plants have come.

Besides the species mentioned above, one sterile specimen of another species was found on Bogue Beach, Beaufort, N. C., August 20, 1908. This has rather thick, leathery leaves borne on short petioles, usually long, oblong, or elliptical, 1.5 to 2.7 cm. long and 5 to 9 mm. wide, a few being short elliptical, 8 to 13 mm. long and 6 to 10 mm. wide, cryptostomata are lacking, the margins are slightly serrate; the vesicles are obovate or rounded, of moderate size, and borne on short stalks. The specimen resembles in some respects herbarium specimens of *S. marginatum* (Ag.) J. Ag. or *S. ilicifolium* (Turn.) Ag., but can not be definitely referred to any species.

Order 3. **Dictyotales** Kjellman.

Tetrasporinæ, De Toni, 1895, p. 325.

Frond of medium size, attached to rocks, etc., light or dark brown, of various forms, usually membranaceous, flat, simple, lobate, or branched, nearly always erect, of parenchymatous structure; asexual propagation by relatively large nonmotile aplanospores, usually produced four (tetraspores), sometimes two or eight, from a mother cell (sporangium); sexual reproduction by relatively large, nonmotile eggs and small, motile, monociliate sperms; sporangia and gametangia on different plants, usually on unspecialized portions of the thallus, developed from superficial cells, occurring singly or in groups (sori), sometimes accompanied by paraphyses; oogonia and antheridia produced on the same or different plants; sexual and asexual generations, at least in some cases, alternating with each other; oogonia producing a single egg; antheridia producing numerous sperms; eggs and sperms discharged into the water where fertilization occurs.

Family DICTYOTACEÆ (Lamouroux) Zanardini.

Characters of the order.

About 120 species, all marine, mostly in warm seas, one species extending to Scandinavia.

KEY TO GENERA.

a. Frond growing by means of single initial cells situated at the apices............5. Dictyota (p. 460).
aa. Frond growing by means of a group or groups of marginal cells situated at the apices............*b*.
  b. Frond zonate by concentric lines of growth, in the neighborhood of which the sporangia and gametangia are developed; fan shaped............*c*.
    c. Hairs lacking on the sterile portions of the frond............1. Zonaria (p. 454).
    cc. Hairs present on the sterile portions of the frond............2. Padina (p. 455).
  bb. Frond uniform, concentric lines of growth lacking; repeatedly dichotomous............*d*.
    d. Midrib lacking............3. Spatoglossum (p. 458).
    dd. Midrib present............4. Dictyopteris (p. 459).

Genus 1. Zonaria Agardh.

Zonaria, Agardh, 1817, p. XX (in part).

Frond flat, fan shaped, often ascending from a prostrate lower part, growing by groups of cells along the apical margins, forming rather vague, scattered zones, divided into more or less narrow segments, often narrowed at the base of the frond and of the separate segments to a subcylindrical, stemlike portion densely covered by short, brown, rhizoidal filaments, this stemlike structure often continued as midribs for short distances on the flattened segments of the lamina; cortex composed of a single layer of cells arranged in pairs forming longitudinal lines radiating like a fan, each row of paired cells corresponding to a single row of interior cells; inner stratum consisting of several layers of cells; sporangia pear shaped, borne in more or less prominent sori, forming scattered, spotlike patches on one or both surfaces of the thallus, covered by the cuticle as an indusium which is burst as the sorus is elevated and soon disappears, sporangia often surrounded by numerous club-shaped, segmented paraphyses, bearing 8 spores; sexual reproduction unknown.

About 15 species in warm and tropical seas.

KEY TO SPECIES.

Frond entire or nearly so, stipe usually 3 to 5 mm. long............1. *Z. variegata* (p. 454).
Frond much divided, stipe usually 1 to 5 cm. long............2. *Z. flava* (p. 455).

1. **Zonaria variegata** (Lamouroux) Mertens. Pl. XCI, fig. 2.

Dictyota variegata, Lamouroux, 1813, pl. 5, f. 7.
Zonaria variegata, Mertens, in Martins, 1828, p. 6, pl. 2, f. 2.
Gymnosorus variegatus, De Toni, 1895, p. 227.
P. B.-A. Nos. 778 (*Gymnosorus variegatus.*), 2028.

Frond flat, fan shaped, rather erect on a short stipe, 3 to 9 cm. tall, 4.5 to 14 cm. wide, stipe 3 to 15 mm. (usually 3 to 5 mm.) long, thallus entire or more or less lobate, marked by variegated markings radiating from the base and by more or less conspicuous, distant, concentric zonations parallel with the apical margin; sori elliptical, forming broken lines or scattered spots between the zonations; texture thin membranaceous or parchmentlike; color olive brown to dark reddish brown.

Florida and West Indies to Brazil; Barbados; Bermuda; Canary Islands; Australian region; Red Sea; Hawaii; Philippines.

Bogue Beach, Beaufort, N. C., one specimen April, 1908, two specimens February, 1909, all sterile.

In this species the concentric zonations are sometimes fairly conspicuous, sometimes invisible to the naked eye. It is easily distinguished from the following species by its smaller size, shorter stipe, radiating markings, and entire or almost entire laminæ, as well as by the absence of continuations of the stipe as "midribs" on the segments.

While the specimens found at Beaufort may have grown on the coral reef offshore, they may equally well have been brought there by the Gulf Stream from Florida or the West Indies. This is the northern known limit of the species and the genus.

2. **Zonaria flava** (Clemente) Agardh. Pl. XCI, fig. 1.

Fucus flavus, Clemente, 1807, p. 310.
Zonaria flava, Agardh, 1817, p. XX.
Zonaria flava, Harvey, 1858, p. 123.
Zonaria flava, De Toni, 1895, p. 230.
A. A. B. Ex. No. 91 (*Zonaria tournefortii*).
P. B.-A. Nos. 86, 1391 (*Zonaria tournefortii*).

Frond rather erect, 3.5 to 17 cm. tall, stipitate, attached by a cushion at the base, parchmentlike, substance almost horny, color reddish brown; stipe subcylindrical, elongated, branched, densely covered by short, brown, rhizoidal filaments; branches going off into a cuneate, flattened lamina, flabellately incised, marked by vague lines radiating from the base and by distant, more or less vague, concentric zonations parallel with the apical margins; stipe continued as midribs for short distances on the flattened segments of the lamina; lamina without midribs for some distance from the apical margins; sori forming irregular, spotlike patches scattered over the surface of the lamina.

California; Brazil; Canaries; Azores; North Africa; Spain; Mediterranean.

Beaufort, N. C.: Very abundant after hard winds, Bogue Beach, throughout the year; very abundant off northwest corner of coral reef at depth of 25.5 m., May, 1907, not found on reef. Fruits throughout the year.

Previously known with certainty from North America only from California, but specimens from Florida in the herbarium of the New York Botanical Garden marked *Z. lobata* Ag. (which species is now referred to *Stypopodium lobatum* (Ag.) Kuetz.) seem to be Zonaria and may belong to this species. This is the northern known limit of the species and of the genus.

The Beaufort specimens resemble the photograph of the type (from Italy) and specimens from California, but many Beaufort plants are larger than any specimens in Herbarium New York Botanical Garden. The California specimens available to the author were 3.5 to 7 cm. tall, small, and narrow, while the Beaufort plants are 7 to 17 cm. tall, large, broad, and much branched.

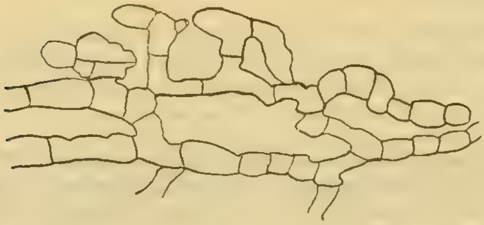
Genus 2. **Padina** Adanson.

Padina, Adanson, 1763, Tome 2, p. 13.

Frond flat, rather erect from a creeping, laterally branched rhizome, growing by groups of cells along the apical margins, forming conspicuous zones marked by concentric bands of short hairs, margin inrolled ventrally, subentire and kidney shaped or fan shaped, or repeatedly divided into spatulate to fan-shaped segments; narrowed at the base to a short, thickened stipe often covered with short, brown rhizoids; lamina sometimes composed of only two layers of cells, usually composed of three or more cell layers differentiated into one-layered, cortical strata and a one or more layered inner stratum; spores produced four in a sporangium; sporangia grouped in sori forming conspicuous scattered patches or more or less regular bands between the zones of hairs, usually covered by a more or less persistent indusium, occurring on one or both sides of the thallus; oogonia and antheridia grouped in sori, occurring on the same or different individuals; in the former case oogonia occurring in concentric bands broken by radial lines of antheridia, in the latter case both oogonia and antheridia occurring in concentric bands between the zones of hairs; oogonia and antheridia produced on one or both sides of the thallus.

About 10 species, in warm and tropical seas.

While this genus is easily recognized, distinctions between the species have been the source of much confusion in the past and are still made with great difficulty in some cases. The characters which are most useful for separating the species and have been used by recent authors are the mutual arrangement of the sori and the lines of hairs, the presence or absence of an indusium covering the sori, and the number of cell layers in the thallus.



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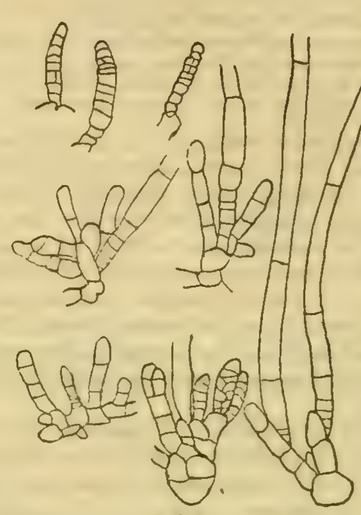

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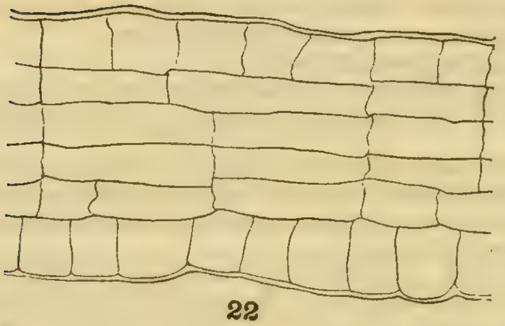

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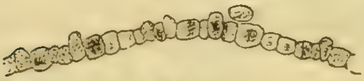

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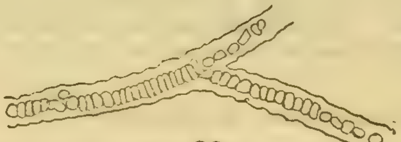

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Fig. 20.—*Elachistea stellulata*, internal filaments branched and anastomosed, × 273.

Fig. 21.—*Elachistea stellulata*, external filaments and "plurilocular sporangia," arising from basal disk as seen in optical section, × 273.

Fig. 22.—*Padina vickersiæ*, cross section of thallus, × 273.

Fig. 23.—*Goniotrichum alsidii*, × 300.

Fig. 24.—*Erythrotrichia carnea*, cells forming spores, × 300.

Padina vickersiæ Hoyt. Fig. 22; Pl. XCII, figs. 1 and 2; Pl. CXIV, figs. 1–3.

Zonaria variegata, Kuetzing, 1859, Bd. 9, p. 30, pl. 73; fig. 2.
Padina variegata, Vickers, 1905, No. 66.
Padina variegata, Vickers, 1908, pl. 8.
Padina vickersiæ, Hoyt, in Britton and Millspaugh, 1920, p. 595.

Thallus erect, flat, expanded, 4 to 22 cm. tall, 5 to 37 cm. broad, entire when young, when mature repeatedly more or less deeply laciniate from the margins into segments, varying from cuneate spatulate to fan shaped, sometimes incrusted with lime, zonate by piliferous lines parallel with the margins, often becoming inconspicuous in the older parts, interpilar zones 1.5 to 6 mm. wide, base consisting of a thickened, rounded stipe 3 to 12 mm. long, densely covered with brown rhizoids, attached by a basal disk; lamina consisting of 3-cell layers near revolute apical margins, of 4-cell layers throughout most of thallus, and of 6 to 8 cell layers toward the base, epidermal cells about half as long as the central cells; tetrasporangia covered by a thin, subpersistent indusium, borne on both surfaces, usually predominantly on the lower surface, occurring in 1 to 2 lines parallel with the apical margin about the middle of each interpilar zone, these lines frequently being broken, the tetrasporangia being scattered throughout the zones on the older portions of the thallus; antheridia and oogonia borne on separate plants (diœcious), occurring in sori in concentric bands, as with the tetrasporangia, borne on both surfaces, usually predominantly on the lower surface, oogonia covered by a thin, subpersistent indusium, antheridia naked (not covered by indusium); texture membranaceous; color light brown, sometimes olivaceous.

Thallo erecto, plano, expanso, 4–22 cm. longo, 5–37 cm. lato, juvenescente integro, maturascente interum atque interum plus minus alte ex marginibus laciniato, segmenta cuneato-spatulata aut flabellata formante, aliquando calce incrustato, zonato ab lineis piliferis cum marginibus parallelis, in regionibus vetustioribus saepe obscurescentibus, zonis interpilis 1.5–6 mm. latis, basi stipe densa rotundata 3–12 mm. longa, rhizoideis fulvis dense tecta, disco basali apta; lamina prope revolutas apicales margines ex tribus stratis cellularum, per maiorem partem thalli ex quattuor stratis cellularum, ad basim ex sex aut octo stratis cellularum constante, cellulæ epidermis circiter dimidio breviores quam cellulae centrales; tetrasporangiis ab indusio tenue et subpersistente tectis, in utraque superficie, plerumque pro maiore parte in inferiore superficie, in lineis unis aut duobus cum margine apicale parallelis circiter in unaquaque media zona interpilula productis, his lineis hinc inde fractis, tetrasporangiis in partibus adultioribus thalli per zonas sparsis; antheridiis et oogoniis ab plantis diversis in lineis concentricis sororum similiter tetrasporangiis, in utraque superficie, plerumque pro maiore parte in inferiore superficie productis; oogoniis ab indusio tenue et subpersistente tectis, antheridiis nudis (et non ab indusio tectis); substantia membranacea; colore dilute fulva, aliquande olivacea.

North Carolina to Florida; West Indies; Barbados; and Bermuda.

Beaufort, N. C.: Very abundant on Fort Macon jetties, 0 to 75 cm. below low tide; extremely abundant on Shackleford jetties and breakwaters, 0 to 1.2 m.; fairly abundant in harbor, June to October; one battered specimen on Fort Macon jetty, December, 1908.

The species here described has often been wrongly referred to *P. pavonia* J. Ag. or to *P. durvillæi* Bory. From the former it is distinguished by the arrangement of the sori, which are in one or two rows about the middle of each interpilar zone, instead of in single lines on both sides of each alternate piliferous line, as in *P. pavonia*. From *P. durvillæi* it is distinguished by the epidermal cells, which are usually about half as long as the central cells, whereas in *P. durvillæi* they are, in all specimens observed by the author, about one-fourth as long as the central cells. Occasionally those of *P. vickersiæ* are as long as the central cells, the two surfaces of the same section sometimes varying in this respect (fig. 22 and Pl. CXIV, figs. 1–3), while those of *P. durvillæi* are said to be half as long as the central cells. In any case, however, the epidermal cells of the present species are about twice as long, compared with the central cells, as those of *P. durvillæi*. In surface view the epidermal cells of *P. vickersiæ* are rectangular, having a length of two or more times their width, while those of *P. durvillæi* are usually about square. The latter species is also coarser and thicker than *P. vickersiæ*, sections showing six cell layers throughout most of the lamina and ten cell layers near the base.

The present species was first figured by Kuetzing (1859, Bd. 9, p. 30, pl. 73, f. 2) under the name *Zonaria variegata*, with the reference "Ag. spec. I. p. 127." This, however, refers to the true *Zonaria variegata* Mertens, whereas the plant figured by Kuetzing is a Padina. Miss Vickers (1905, No. 66) names this species *P. variegata* with the reference "*Zonaria variegata* Kuetz." Even if the rules of nomenclature allowed the recognition of a *Zonaria variegata* of Mertens and another of Kuetzing, the name *P. variegata* is rendered invalid by the fact that neither Kuetzing nor Miss Vickers published a description of the species. The citation of Börgesen (1914, p. 205 [49]) to *P. variegata* (Lamouroux) Hauck seems even less warranted. According to Howe (1915, pp. 49–50), *Dictyota variegata* Lamouroux seems, from both the published figures and the extant specimens of Lamouroux, to have been exclusively *Zonaria variegata*. Hauck's use of the name *Padina variegata* is merely an incidental mention and is founded only on a reference to Kuetzing. For both of these reasons this use of the name does not seem to constitute valid publication. In view of these facts, it has seemed necessary to give a new name to the species.

Our species, however, approaches very near to *P. dubia* Hauck (1887, p. 45) and may be identical with this. In Herb. Hauck there are four good unmounted specimens of *P. dubia* with a loose label written by Hauck. In habit, size, and number of cell layers they resemble the present species; the sori are often irregularly scattered over almost the entire surface but in parts are in regular zones just above each piliferous line.[a] The available material has not been sufficient to determine whether the distribution of the sori is the same as that of *P. vickersiæ*, but it is certainly closely similar ("*P. variegata*" and *P. dubia* being placed in the same group by Hauck on the basis of this character), and in other respects the two species seem identical. It seems, therefore, very probable that these belong to a single species. But, in view of some uncertainty regarding similarity in the arrangement of the sori and in view of the opinion expressed by Hauck that his material of *P. dubia* did not entirely agree with the "*Zonaria variegata*" of Kuetzing, it has seemed better to keep the species separate until *P. dubia* can be more thoroughly studied. If the two are found to belong to a single species, both *P. variegata* (Kuetz.) Vickers and the present name must be reduced to synonyms.

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[a] The author is gratefully indebted to Dr. Marshall A. Howe for permission to quote from his notes on *P. dubia* as found in Herb. Hauck, as well as for the opportunity to study portions of two of the original specimens of this species.

The type of the species here described is a tetrasporic plant from Fort Macon jetty, Beaufort, N. C., August 23, 1907. This and several cotypes have been deposited in the U. S. National Herbarium.

The tetrasporangia, oogonia, and antheridia are borne on separate plants (the species being diœcious), and the sexual and asexual generations seem, from the results of Wolfe (1913, 1918), to alternate with each other as in Dictyota. There is evidence (Wolfe, 1918), for believing that the eggs may be fertilized before being discharged from the oogonium. Unfertilized eggs may commence their development parthenogenetically as in Dictyota, but apparently never (Wolfe, 1914, 1918), under such conditions, reach maturity. According to observations of Howe, [a] the tetrasporangia also may commence development without undergoing division, forming many-celled brood buds or propagula. The further history of these bodies is unknown.

The portions of the cuticle covering the sori are raised by the developing tetrasporangia and oogonia as distinct indusia covering the fruiting areas (Pl. CXIV, figs. 1-3), while those covering the antheridia are not raised as distinct layers, and the antheridia accordingly appear naked. Although Börgesen (1914) figures an indusium covering the antheridial sorus, the author, after careful study of sections of well-preserved material, has been unable to find these in any case. In spite of this discrepancy, the plants of Börgesen and those referred to here almost certainly belong to the same species. The indusia, when present, are very delicate and are finally ruptured by the developing sori; they are, consequently, often absent from mature fruits and frequently are not evident on dried plants. The tetrasporic and female plants closely resemble each other but can easily be distinguished by the fact that the tetrasporangia have about twice the diameter of the oogonia, mature tetrasporangia measuring 41 to 90 by 47 to 108 mic. and the oogonia 27 to 45 by 36 to 63 mic. Frequently, moreover, all the oogonia on a single plant are of the same age, while the tetrasporangia, although usually of the same age in a single zone, are borne in successively younger zones toward the apical margins. There is some evidence that the sexual cells are borne in periodic crops at weekly intervals, but in other cases oogonia (or antheridia) of several different ages are borne on the same individual.[b]

Two other species of Padina are recorded from the West Indies. These, if found, may be distinguished from the present species by the following characters:

P. sanctæ crucis Börgesen.—Frond consisting of two cell layers, tetrasporangial sori in concentric zones above each alternate line of hairs.

P. gymnospora (Kuetzing) Vickers.—Frond consisting of three cell layers, tetrasporangial sori in concentric zones in middle of each alternate zone between the lines of hairs, sori not covered by indusia.

Genus 3. **Spatoglossum** Kuetzing.

Spatoglossum, Kuetzing, 1843, p. 339.
Spathoglossum, De Toni, 1895, p. 246.

Frond flat, ribbonlike, subpalmate-dichotomous, growing by groups of cells at the apices, surface uniform, zonations lacking; margin smooth or dentate; midrib lacking; cortex composed of a single layer of cells arranged in straight parallel lines; inner stratum composed of several layers of cells; spores produced four in a sporangium; sporangia scattered over both surfaces, occurring singly or several together in small groups; oogonia and antheridia produced on different plants; oogonia occurring singly, scattered over the surface; antheridia in small, scattered, inconspicuous sori.

About eight species, in warm and tropical seas.

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[a] The author is gratefully indebted to Dr. Marshall A. Howe for permission to refer to these unpublished results.

[b] The author is indebted to Prof. J. J. Wolfe for considerable information regarding the life habits of Padina at Beaufort.

Spatoglossum schrœderi (Mertens) J. Agardh. Pl. XCIII, fig. 1; Pl. XCIV, fig. 2 a and b.

Ulva schrœderi, Mertens, in Martins, 1828, pl. 2, f. 3.
Taonia schrœderi, Harvey, 1852, p. 107.
Spatoglossum schrœderi, J. Agardh, 1880a, p. 113 (in part).
Spathoglossum schrœderi, De Toni, 1895, p. 249.
A. A. B. Ex. No. 159 (*Taonia schrœderi*).
P. B.-A. Nos. 326, 2027.

Frond membranaceous, thin, dichotomous, or sometimes subpalmate with approximate segments and irregularly decompound above by new segments sprouting from the margins; these segments somewhat contracted at their bases; margin entire in younger portions, later distinctly distantly serrate; color yellowish brown.

Florida to Brazil; West Indies; Bermuda; Guadeloupe.

Beaufort, N. C.: Three plants in one small mass on Fort Macon jetty, August, 1906; few fragments dredged from coral reef offshore August, 1914 and 1915.

This species often closely resembles *Dictyota dichotoma*, from which it is easily distinguished by its groups of initial cells at the apices of the branches and by its serrate margins. All three of the plants from Beaufort Harbor were fruiting abundantly, bearing numerous tetrasporangia scattered thickly over both surfaces. The plants from the coral reef have decidedly dentate margins, while those found growing in the harbor have almost smooth margins with only a few ciliate projections.

This is the only species of this genus known from North America, *Spatoglossum areschougii* J. Ag. (which has been listed for this continent), now being regarded as belonging to the present species.

This is the northern known limit of the species and of the genus.

Genus 4. **Dictyopteris** Lamouroux.

Dictyopteris, Lamouroux, 1809a, p. 129.
Haliseris, De Toni, 1895, p. 253.

Frond erect, flat, more or less regularly dichotomous, growing by groups of cells at the apices, surface uniform, zonations lacking; provided with a conspicuous midrib and, in some species, with veins running from the midrib to the margins; lamina transient in the basal portion, the frond finally consisting in this region of the persistent midrib forming a stemlike structure; cortex composed of a single layer of cells; inner stratum composed of several layers of cells; spores produced four in a sporangium; sporangia occurring in sublinear or spotlike sori on both sides along the midrib on both surfaces of the frond; oogonia and antheridia produced on the same plant; oogonia occurring singly, scattered over both surfaces; antheridia in small inconspicuous, scattered, slightly sunken sori, especially in the region of the midrib.

About 14 species, in warm and tropical seas.

It is interesting that both the species found at Beaufort should be new to North America. *D. serrata* has an especially interesting distribution, being previously reported only from the eastern coast of Africa and from the present locality.

KEY TO SPECIES.

Margin smooth or undulate, often lacerate, not serrate; no nerves running from midrib............ 1. *D. polypodioides* (p. 459).
Margin serrate; nerves running from midrib to margins.......... 2. *D. serrata* (p. 460).

1. **Dictyopteris polypodioides** (Desfontaine) Lamouroux. Pl. XCIII, fig. 2.

Fucus polypodioides, Desfontaine, 1798, Tom. 2, p. 421.
Dictyopteris polypodioides, Lamouroux, 1809a, p. 131.
Haliseris polypodioides, De Toni, 1895, p. 254.

Frond 7.5 to 72 cm. long, 0.4 to 1.2 cm. wide, on a more or less elongated subterete stipe; color olive brown; repeatedly dichotomous, with occasional branches arising laterally and from the midrib on the flat surface of the frond; numerous groups of short hairs scattered over the lamina; sinuses rather acute, segments patent, attenuated at the apices; margins entire or often lacerate, smooth, often undulate; no nerves running from midrib; tetrasporangia in small or large, inconspicuous, more or less confluent sori along both sides of the midrib; antheridial sori uniformly scattered over the frond.

Brazil; Europe; Tasmania; Red Sea; Arabian Gulf.

Beaufort, N. C.: Occasional on rocks of Fort Macon jetties, summer and autumn; occasional on Bogue Beach, spring, summer, and autumn; extremely abundant alongshore for distance of more than 22 km. from New River Inlet, south of Beaufort, and extending at least 12 km. offshore, at depth of 5.8 to 12 m., August, 1914; very abundant in trawl offshore from Browns Inlet, south of Beaufort, July, 1915.

This species has not previously been reported from North America. The specimens from this region closely resemble specimens from England and France. Those from New River Inlet are the largest which have been observed by the author.

2. **Dictyopteris serrata** (Areschoug) comb. nov. Pl. XCIII, fig. 3.

Haliseris serrata, Areschoug, 1847, p. 4, pl. 7.
Haliseris serrata, De Toni, 1895, p. 259.

Frond 8 to 30 cm. long, 1.4 to 3 cm. wide, on an elongated, slightly flattened stipe; color yellow brown; sparingly dichotomous; hairs occurring in scattered groups over the lamina; sinuses subrotund, segments patent, attenuated at the apices; margins usually entire, with acute, approximate, or more distant serrations; lamina furnished with more or less numerous, fairly conspicuous nerves running from the midrib obliquely toward the margins; sporangial sori small and inconspicuous, in more or less regular lines parallel to the veins in the intervenous spaces; oogonia produced on both surfaces, scattered over the frond, especially along midrib and margins.

Port Natal, Africa; Mauritius.

Fairly abundant July and August, 1903, Bogue Beach, Beaufort, N. C., occasional in spring, summer, and fall of other years; several large plants dredged from the coral reef offshore, August, 1914, and August, 1915.

This species has been previously reported only from Port Natal, Africa, but a specimen in the herbarium of the New York Botanical Garden was collected in Mauritius. The Beaufort specimens differ from the description in having slightly more rounded apices and slightly less rotund sinuses. They sometimes differ from the plate in Kuetzing (Tab. Phyc. IX, pl. 60) and from the specimen in the herbarium of the New York Botanical Garden in having less conspicuous veins and smaller, more numerous serrations. From the latter specimen they sometimes differ also in having a lighter color and a thinner texture, the inner stratum consisting of one to two layers of cells instead of uniformly two layers, as in that specimen. In spite of these differences there seems no doubt that the specimens from Beaufort are correctly referred to *D. serrata*. They certainly belong to Dictyopteris and, if not this species, must be described as a new one. The differences do not seem sufficient to warrant the description of a new species.

In the Beaufort plants the apices are sometimes sunken, as in fern prothalli. In one specimen the veins occasionally, instead of running out to the margins, form plexuses of small veins between the midrib and the margin and between the dichotomies of the midrib. Both tetrasporangia and oogonia have been observed on the Beaufort specimens.

Genus 5. **Dictyota** Lamouroux.

Dictyota, Lamouroux, 1809c, p. 331.
Dictyota, Lamouroux, 1809, p. 38.

Frond erect, flat, ribbonlike, sometimes rising from a rhizomelike, rounded portion, usually regularly dichotomous, growing by a single initial cell at the apex of each branch, surface uniform, zonations lacking; no midrib present; cortex composed of a single layer of small cells; inner stratum composed of a single layer of rather large cells; spores produced four in a sporangium; sporangia occurring singly or in small groups scattered over both surfaces of the frond; oogonia and antheridia produced on different plants, in conspicuous roundish or ellipsoidal sori, scattered over both surfaces; oogonial sori black, antheridial sori whitish.

About 37 species in warm and temperate seas, one extending to Scandinavia.

Dictyota dichotoma (Hudson) Lamouroux. Pl. XCIV, figs. 1, 2 c and d, and 3.

Ulva dichotoma, Hudson, 1762, p. 476.
Dictyota dichotoma, Lamouroux, 1809, p. 42.
Dictyota dichotoma, Harvey, 1852, p. 109.
Dictyota dichotoma, De Toni, 1895, p. 263.
P. B-A. Nos. 282, 1641, 2175. Fasc. E. No. CXX.

Frond erect, flat, ribbonlike, sometimes narrowed at the base to a very short stipelike portion, attached by a small, padlike thickening; regularly dichotomous, sometimes with irregular branches given off from the apices and from the margins; margins smooth, entire; apices usually rounded, obtuse, sometimes rather acute; tetrasporangia, and oogonial and antheridial sori scattered all over both surfaces except base, tips, and margins; tetraspores produced continuously, not in regular crops; oogonia and antheridia produced in crops at regular intervals; sexual and asexual plants showing a regular alternation of generations.

Reported from warm and temperate waters generally, extending in Europe as far north as Norway and Helgoland.

Very abundant on Fort Macon and Shackleford jetties, Beaufort, N. C., and in harbor from low water to 1 m. below low water, and occasionally abundant on Bogue Beach, June to October; fairly abundant in Newport River near "Green Rock"; abundant in North River off Lennoxville and Marshallburg; one small mass floating in Core Sound off Davis Island; two plants 2 cm. long on coral reef off Beaufort, N. C., May, 1907, and fairly abundant, August, 1914 and 1915. Abundant in sound near Moores Inlet, Wrightsville Beach, N. C., July to September, 1909.

This is the northern known limit in North America of the species and of the genus.

The species varies considerably in size, width, amount of branching, and acuteness of apices, varying from plants 1 to 3 mm. wide and 6.5 cm. long to plants 4 to 16 mm. wide and 29 cm. long. The average of six well-developed plants from Beaufort was 4 to 12 mm. wide, 18 cm. long. The branching may be frequent, forming a short, dense habit, or may be infrequent, forming a long, open habit. The apices, while usually obtuse, may be acute. The Beaufort plants, while varying in these respects, show less variation than English specimens.

All the specimens of this species dredged from the coral reef, August, 1914, were very narrow and finely divided, with numerous almost linear proliferations (Plate XCIV, fig. 2 *c* and *d*).

Plants from unfavorable situations are narrow, often spirally twisted, and usually small. The apices of these plants are often acute. Some apices of larger plants may be acute at times, since, when conditions are changed to less favorable ones or sometimes after fruiting, there are formed narrow projections from the apices. These may widen out later or may grow out as proliferations from the apices, later widening out and branching dichotomously. Plants collected at the beginning of this process, if examined by themselves, would often be determined as *D. bartayresiana* Lamour. Under different conditions of growth plants may resemble *D. bartayresiana* Lamour., *D. divaricata* Lamour., *D. dichotoma* f. *latifolia* (Kuetz.) Vinassa, f. *attenuata* (Kuetz.) Vinassa, or f. *implexa* (Lamour.) Vinassa. These three last-named forms are at Beaufort only growth forms occurring under different conditions in the environment. *D. bartayresiana* can itself not be sharply distinguished from *D. dichotoma*, since specimens of these species may overlap. Many specimens of *D. dichotoma* from England are narrower and more acute at the apices than shown in photographs of the type of *D. bartayresiana*.

D. dichotoma, wherever carefully observed, has been found to produce its sexual cells in regular periodic crops. In the three European stations where this process has been studied—Bangor, Wales, and Plymouth, England (Williams, 1905), and Naples, Italy (Lewis, 1910)—the plants produce two crops a month at regular intervals related to the tidal seasons, the relations of the crops to the tides varying in the different localities. At Beaufort (Hoyt, 1907), only one crop a month is produced, this being initiated from three days before up to the day of the greatest springtide at the time of the full moon, as shown by the tide tables, and being liberated from three to six days after the day of the greatest springtide. The relation between the greatest springtide and the times of initiation and liberation of the crop varies within the given limits in different summers but is fairly constant in any one summer. At Beaufort and Naples, and probably elsewhere, the sexual cells are liberated at or a little before dawn.

In spite of this great difference in the production of their crops, the close morphological similarity of the Beaufort plants to those of Europe seems to preclude the placing of these in a separate species. The facts mentioned above, however, show that the characters which have been used to separate certain species—the size and width of plants and the acuteness of the apices—are not by themselves safe characters for specific distinctions.

The studies of Williams (1904, 1904a) and the cultures of Hoyt (1910) have shown that in this species the sexual and asexual generations alternate with each other in regular succession.

Division IV. RHODOPHYCEÆ Ruprecht.

Rodospermeæ, Harvey, 1852, p. 1.
Florideæ, Farlow, 1882, p. 106.
Florideæ, De Toni, 1897, p. 1.

RED ALGÆ.

Algæ colored rose, crimson, or purple, less often violet, olivaceous, green, or blackish, containing in their cells endochrome composed of chlorophyll, and a characteristic red pigment (phycoerythrin) mixed with other pigments; endochrome contained in definite chromatophores; thallus varying greatly in size and form, composed of segmented, separate, or more or less coalescent filaments; cells containing one or more nuclei. Multiplication asexual or sexual. Asexual propagation usually by spores, sometimes by brood cells or brood buds; spores usually produced four (tetraspores), sometimes one (monospore), two, or many in a sporangium, at first naked, later inclosed by a membrane, usually nonmotile, in some cases possessed for a time of slight amœboid movement, but apparently always passively distributed; sporangia external or immersed, distributed over the thallus or borne on more or less specialized portions. Sexual reproduction by the fusion of dissimilar male and female gametes borne on the same or different individuals. Male gametes (spermatia) naked, nonmotile, produced one or many in a more or less specialized antheridium, discharged into the water and passively transported; antheridia usually external, sometimes immersed, borne on specialized or unspecialized portions of the thallus, in the Bangiales formed by the transformation and division of ordinary vegetative cells. Female gametes occurring singly within special organs, never escaping free into the water. These organs, usually immersed, sometimes external, are, in the Bangiales, formed by the direct transformation of swollen vegetative cells; in the Florideæ they are borne at the ends of short, usually three or four celled filaments (carpogenic branches) each organ (carpogonium) consisting of a swollen basal portion and a hairlike, apical prolongation, the trichogyne. Associated with these organs in reproduction there are, in most orders of the Florideæ, special cells, auxiliary cells, which are either joined with the carpogonium in a common structure, the procarp, or occur separately in the thallus more or less near the carpogonia. In the fusion of male and female gametes a spermatium is floated to the trichogyne and fuses with this, the male nucleus passing down and fusing with the female nucleus in the swollen basal portion of the carpogonium. This fertilized egg cell then either directly produces tufts of spore-bearing filaments (gonimoblasts), or, in most orders, gives off longer or shorter filaments bearing the fertilized egg nucleus or some of its descendants, these filaments fusing with the auxiliary cells, and the auxiliary cells then giving rise to spore-bearing filaments. The fruits thus produced (sporocarps) are often inclosed by a more or less specialized sterile jacket, the whole structure constituting the cystocarp. The nonmotile spores (carpospores) borne in these fruits are discharged into the water and germinate immediately. Carpogonia and sporocarps are borne externally or immersed on specialized or unspecialized portions of the thallus. Sexual and asexual cells are nearly always produced on different individuals, the sexual and asexual plants, at least in some cases, alternating with each other in the life cycle; antheridia and carpogonia are borne on the same or different individuals. Almost exclusively marine, a few in fresh water, some endophytic.

About 3,000 species throughout the world but most abundant in warm seas.

KEY TO CLASSES.

Thallus filamentous or foliaceous, usually unbranched; asexual and sexual organs formed from ordinary vegetative cells..1. BANGIOIDEÆ (p. 463).

Thallus variously formed, usually branched; asexual spores (usually four) produced in special sporangia; sexual gametes borne in antheridia and carpogonia.............2. FLORIDEÆ (p. 467).

Class 1. Bangioideæ De Toni.

This class contains only one order.

Order **Bangiales.** Schmitz and Hauptfleisch.

Thallus filiform, disk shaped or foliaceous; asexual propagation by spores produced from ordinary vegetative cells or by akinetes; sexual reproduction by apparently nonmotile spermatia and eggs produced from ordinary vegetative cells.

Family BANGIACEÆ (Zanardini) Berthold.

Thallus small or of medium size, attached to rocks, etc., colored various shades of red or purple, sometimes blue or greenish, sheets of one or two layers of cells, or of disks, or of filaments composed of one or more cell rows; cells having a single nucleus and a single star-shaped chromatophore; asexual propagation by spores produced one or more from ordinary vegetative cells, occasionally by akinetes; sexual reproduction by minute, apparently nonmotile spermatia, which are discharged into the water, and large eggs which are retained within the enveloping organ; numerous spermatia formed by division of ordinary vegetative cells which function as antheridia; eggs usually produced singly, formed from ordinary vegetative cells, which may in some cases be regarded as simple carpogonia, since they frequently form hairlike protuberances somewhat similar to the trichogynes of Florideæ, the spermatia then fuse with these protuberances; the fertilized egg divides into a few (usually eight) spores, or, rarely, may be transformed directly into a single spore; both the sexually produced and the asexual spores are naked when first discharged into the water, and frequently are possessed of slight amœboid movement, but are soon surrounded by walls and apparently are always passively transported. Asexual and sexual organs are, in different species, produced on the same or on different individuals, as is also the case with male and female organs.

About 45 species, nearly all marine, a few in fresh water, throughout the world, especially in temperate seas.

KEY TO GENERA.

a. Asexual spore formed from the contents of a vegetative cell without division, sexual reproduction apparently lacking .... 3. Goniotrichum (p. 465).
aa. Asexual spore formed from the smaller of two cells arising from the unequal division of a vegetative cell by an oblique wall, sexual reproduction usually present .... *b*.
b. Thallus consisting of erect filaments .... 4. Erythrotrichia (p. 466).
bb. Thallus consisting of branched filaments creeping on or in the surface of other algæ, and more or less fusing to form a single-layered disk .... 5. Erythrocladia (p. 466).
aaa. Asexual spores formed by approximately equal division of a vegetative cell (sometimes without division), sexual reproduction present .... *c*.
c. Thallus filiform .... 1. Bangia (p. 464).
cc. Thallus membranaceous, flat .... 2. Porphyra (p. 464).

Genus 1. **Bangia** Lyngbye.

Bangia, Lyngbye, 1819, p. 82.

Thallus erect, filiform, unbranched, attached by an expanded base, more or less thickened above, terete, commonly irregularly constricted, sometimes tubular and hollow above. Asexual spores, formed from the entire contents of vegetative cells or from cells formed by one (or sometimes two) divisions of vegetative cells, are discharged into the water and germinate immediately. Numerous spermatia formed by repeated division of vegetative cells which function as antheridia. Eggs arising singly from the entire contents of enlarged vegetative cells. Fertilized eggs divide into a few (usually eight) spores, which are discharged into the water and apparently germinate immediately. Asexual and sexual organs borne on the same or on different individuals, male and female organs produced on the same or different individuals.

About 10 species described, but not sharply separated, mostly marine, occasionally in fresh water.

Bangia fusco-purpurea (Dillwyn) Lyngbye.

Conferva fusco-purpurea, Dillwyn, 1809, pl. 92.
Bangia fusco-purpurea, Lyngbye, 1819, p. 83, pl. 24 C.
Bangia fusco-purpurea, Farlow, 1882, p. 112.
Bangia atro-purpurea, var. *fusco-purpurea*, De Toni, 1897, p. 112.
P. B.-A. Nos. 87, 2084.

Thallus filamentous, erect, 0.5 to 15 cm. long, attached to rocks, etc., variable in color and size, pink to purple, younger filaments composed of one or two rows of cells, older filaments forming a hollow tube.

Cold and temperate North Atlantic and Pacific; Mediterranean.

Abundant between tide lines on rocks of Shackleford jetty, Beaufort, N. C., May, 1907, and fairly abundant on Shackleford and Fort Macon jetties, April, 1908; probably occurs from December to May.

Specimens vary greatly in appearance on account of their differences in size and color; the filaments vary from a fineness that is indistinguishable to the naked eye to the thickness of a coarse hair; the cells vary greatly in diameter.

This is the southern limit reported for the species, but specimens are known from points farther south, and the species will probably be found to extend along our entire coast during the winter.

Genus 2. **Porphyra** Agardh.

Porphyra, Agardh, 1824, p. XXXII.
Porphyra, De Toni, 1897, p. 13.
Wildemania, De Toni, 1897, p. 20.

Thallus erect, foliaceous, flat and thin, margin entire, lobate or laciniate, often undulate, attached by a basal disk, base substipitate; at first consisting of a simple filament, soon developing into a flat membrane consisting of one or two cell layers; propagation and reproduction as in Bangia; spore fruit consisting of eight or more cells.

About 20 species, all marine, many of them not sharply separated.

Porphyra leucosticta Thuret.

Porphyra leucosticta, Thuret, in Le Jolis, 1863, p. 100.
Porphyra atropurpurea, De Toni, 1897, p. 17.
P. B.-A. No. 376.

Frond shortly stipitate, attached by a basal disk, consisting of a single layer of cells (except during reproduction), variable in color from pink or red to purple and in form from indefinite sheets to narrow bands, simple or variously divided, 2 to 40 cm. long, 0.5 to 14 cm. wide; monœcious, antheridia forming small, elongated, colorless patches among the darker female organs.

Temperate North Atlantic and Pacific; Mediterranean.

Very abundant between tide lines throughout harbor and on jetties, Beaufort, N. C., January to May.

At Beaufort the plants are kidney shaped to linear, lanceolate and laciniate, 3 to 10 cm. long, of a pinkish or brownish purple color.

Another species, *P. laciniata* (Lightf.) Ag. has not been observed in this region, but may be found here at times, although it is, in general, a more northern form than *P. leucosticta*. These species can not be separated by form or color, but are distinguished as follows: *P. leucosticta*, monœcious, antheridia occurring in small, elongated, colorless patches; *P. laciniata*, usually diœcious, antheridia forming a colorless marginal zone.

Genus 3. **Goniotrichum** Kuetzing.

Goniotrichum, Kuetzing, 1843, p. 244 (in part).

Thallus erect, filamentous, consisting of a single row of cells, exhibiting "false branching," or, occasionally, laterally branched; cells rose colored, containing single, star-shaped chromatophores and single nuclei; cell walls soon becoming gelatinous; asexual propagation by transformation of vegetative cells into monosporangia, their contents soon escaping as naked monospores; sexual reproduction unknown.

Two species recognized.

The members of this genus are peculiar in combining characters of the blue-green and the red algæ. In their possession of "false branching" and gelatinous sheaths formed by the swelling of the cell walls inclosing the filaments, they resemble the Myxophyceæ, while the structure of their cells, and especially their method of propagation, place them among the Bangiaceæ in the Rhodophyceæ.

Goniotrichum alsidii (Zanardini) Howe. Fig. 23.

Bangia alsidii, Zanardini, 1839, p. 136.
Goniotrichum elegans, Zanardini, 1847, p. 254 (69).
Goniotrichum elegans, Forti, in De Toni, 1907, p. 687.
Goniotrichum elegans, Tilden, 1910, p. 295.
Goniotrichum alsidii, Howe, 1914a, p. 75.
P. B.-A. No. 781.

Filaments red, 1 to 5 mm. long, inclosed in gelatinous sheaths; cells cylindrical or elliptical, 7 to 10 mic. wide, 11 to 20 mic. long; sheaths 2 to 6 mic. wide on each side of filament, often with crenate edges.

Warm and temperate North Atlantic.

Occasional on other algæ and on eel grass (*Zostera marina*), usually occurring in very small quantities, abundant on one old specimen of *Padina vickersiæ*, Fort Macon jetty, December, 1908, and occasional on various algæ dredged from coral reef offshore, Beaufort, N. C., August, 1914 and 1915.

Genus 4. **Erythrotrichia** Areschoug.

Erythrotrichia, Areschoug, 1850, p. 209.

Thallus erect, filiform, attached below by a dilated basal cell or a few-celled disk, above filamentous or more or less thickened and terete or dilated and foliaceous; cells at first arranged in a single row, later sometimes divided longitudinally, or occasionally even forming a one-layered disk; asexual propagation by naked monospores which are passively distributed; monosporangium formed from the upper, smaller, denser of two cells arising from the unequal division of a vegetative cell by an oblique wall; sexual reproduction by apparently nonmotile spermatia and eggs; antheridia formed from portions of vegetative cells in a way analogous to the monosporangia, the contents being divided into numerous minute spermatia; eggs arising singly from the entire contents of vegetative cells; fertilized egg forming a one or few celled fruit.

About five species, all marine.

Erythrotrichia carnea (Dillwyn) J. Agardh. Fig. 24.

Conferva carnea, Dillwyn, 1809, pl. 84.
Conferva ceramicola, Lyngbye, 1819, p. 144, pl. 48 D.
Erythrotrichia ceramicola, Areschoug, 1850, p. 210.
Erythrotrichia carnea, J. Agardh, 1882, p. 15, pl. 19.
Erythrotrichia ceramicola, Farlow, 1882, p. 113.
Erythrotrichia ceramicola, De Toni, 1897, p. 24.
P. B.-A. No. 1642 (*Erythrotrichia ceramicola*).

Thallus epiphytic, consisting of erect, flaccid filaments 1 to 30 mm. long, composed of single, unbranched rows of cells, attached by the expanded, colorless basal cell of each filament; cells 12 to 20 mic. long, 12 to 18 mic. wide, rose or flesh color; monospores spherical, 15 to 18 mic. in diameter.

Warm and temperate North Atlantic; Alaska; Adriatic.

Common in small quantities on *Dictyota dichotoma* and *Padina vickersiæ*, Beaufort, N. C., June to December, and on *Dictyota dichotoma* at Marshallburg, N. C. On old specimens of these species it becomes very abundant, either mixed with other filamentous epiphytic algæ or covering the entire host plant with a pure growth.

Genus 5. **Erythrocladia** Rosenvinge.

Erythrocladia, Rosenvinge, 1909, p. 71.

Thallus horizontally expanded, growing on or in other algæ, composed of branched filaments irregularly or more or less regularly radiating from a common center, separate from each other in the beginning, later fusing more or less to form a thin disk consisting of a single layer, filaments growing at the apices; asexual propagation by naked monospores which are passively distributed; monosporangium formed from the denser of two cells arising from the unequal division of a vegetative cell by an oblique wall; sexual reproduction by apparently nonmotile spermatia and eggs; spermatia (at least in some cases) raised slightly above the surface; carpogonium furnished with a short beak or trichogyne projecting slightly beyond the surface; fertilized egg forming a small fruit (sporocarp) bearing one or more carpospores.

Four species, known only from Denmark, North Carolina, and, with some doubt, from St. Thomas, West Indies.

KEY TO SPECIES.

Mature thallus consisting of filaments forming an irregular suborbicular structure, the filaments somewhat compact and coalescent at the center and radiating from this toward the edges, cells 8 to 25 mic. long and 3 to 12 mic. broad ....1. *E. recondita* (p. 467).
Mature thallus consisting of straggling or irregularly radiating filaments, not forming a compact structure at the center, cells 9 to 40 mic. long and 6.5 to 15 mic. broad. .2. *E. vagabunda* (p. 467).

1. **Erythrocladia recondita** Howe and Hoyt. Pl. CXVI, fig. 1; Pl. CXVII, figs. 1–5.

Erythrocladia recondita, Howe and Hoyt, 1916, p. 112, pl. 12, figs. 1–5; pl. 13, fig. 1.

Thallus endophytic or pseudo-epiphytic, creeping in the superficial cell walls of other algæ, consisting at first of free, irregularly radiating, and irregularly branching filaments, soon forming a more or less compact central region by the coalescence of the central filaments, the entire structure reaching a diameter of 0.2 to 1.5 mm. and usually remaining single-layered; branching lateral or somewhat dichotomous, the lateral branches, especially in the younger parts, often spreading; cells varied and irregular in form, in surface view mostly oblong, quadrate, ovate, or fiddle shaped, often curved, forked, or irregularly one or two lobed, 8 to 25 mic. long, 3 to 12 mic. broad; male and female organs borne on the same individual; spermatia ovoid, 2 to 4 mic. in diameter, more or less exserted by slender stalks about 1 mic. broad; carpogonium furnished with a beak or trichogyne exserted about 4 to 8 mic.; sporocarp forming a single carpospore (or, rarely, two), these ovoid, oblong, or irregular, mostly 8 to 19 mic. in maximum diameter; nonsexual spores unknown.

Endemic.

Fairly abundant in the superficial cell walls of *Dictyota dichotoma* growing in the harbor, Beaufort, N. C., especially on Fort Macon jetties, summer and autumn; on Dictyota and other algæ and in the stolons of hydroids growing on these, dredged from the coral reef offshore, Beaufort, N. C., August, 1914.

This alga is entirely invisible to the naked eye and will not be seen even under the microscope unless a careful search is made. When seen, it appears as a more or less definite mass of clear, minute filaments closely adherent to the surface of the host. Its color is scarcely distinguishable, it apparently being so neutral in this respect as to show the color of the host. It can be made clearly evident by staining with iodine dissolved in potassium iodide. It will not be confused with any other species found in the harbor. It is unknown outside of this region.

2. **Erythrocladia vagabunda** Howe and Hoyt. Pl. CXVI, fig. 2; Pl. CXVII, figs. 6–11.

Erythrocladia vagabunda, Howe and Hoyt, 1916, p. 115, pl. 12, figs. 6–11, pl. 13, fig. 2.

Thallus endophytic or pseudo-epiphytic, creeping in the superficial cell walls of other algæ, consisting chiefly of irregularly branching, uniaxially elongate, or irregularly radiating filaments, finally spreading over areas 0.75 to 2.25 mm. long or broad, often anastomosing or appearing to anastomose, and commonly forming here and there small irregular compact patches 2 to 6 cells broad; branching mostly lateral, rarely somewhat dichotomous, often spreading or rectangular; cells for the most part irregularly oblong in surface view, often curved or one or two lobed, 9 to 40 mic. long, 6.5 to 15 mic. broad; sporocarps forming single carpospores (rarely two?), these ovoid, oblong, or irregular, mostly 12 to 25 mic. in maximum diameter; nonsexual spores unknown.

Endemic.

Fairly abundant in the superficial cell walls of *Dictyota dichotoma* dredged from the coral reef offshore, Beaufort, N. C., August, 1914.

This species is not visible to the naked eye and will not be noticed, even under the microscope, unless a careful search is made. Staining with iodine dissolved in potassium iodide will help to make it evident. It has not been found in the harbor. If it should be found there, it will not be mistaken for any other alga except *E. recondita*. From this it is distinguished by its more straggling habit, its larger cells, and its more rectangular branches. It is not known from any other region.

Plants apparently belonging to this species were found on *Sargassum filipendula* dredged from the coral reef at the same time as the Dictyota.

Class 2. Florideæ Lamouroux.

Eu-Florideæ, De Toni, 1897, p. 33.

Thallus multicellular, exceedingly various in size, habit, and structure; asexual propagation by nonmotile spores produced (usually four—tetraspores, sometimes one, two, or many) in special sporangia; tetrosporangia divided zonately, cruciately, or triangularly; sexual reproduction by nonmotile spermatia and eggs borne in special antheridia and carpogonia, respectively; antheridia variously formed, producing numerous minute spermatia; carpogonia bearing single eggs which, when fertilized, give rise to spore-bearing filaments directly or in conjunction with auxiliary cells; auxiliary cells present, except among Nemalionales, associated with the carpogonium or occurring separately in the thallus, sometimes not developed until after fertilization; tufts of spore-bearing filaments (gonimoblasts), formed as result of fertilization, entire or divided into several parts (gonimolobes); each filament giving rise to a single nonmotile spore (carpospore) from each of one or more of its apical cells; gonimoblasts naked or inclosed by sterile jackets, forming cystocarps opening by apical pores.

KEY TO ORDERS.

a. Gonimoblasts formed directly from the fertilized eggs..................1. NEMALIONALES (p. 468).

aa. Gonimoblasts formed with the interposition of auxiliary cells..................................*b*.

- *b*. Auxiliary cells usually united with carpogenic branches into definite procarps, cystocarps usually immersed in the frond, gonimoblasts not attached to a basal placenta ....2. GIGARTINALES (p. 476).
- *bb*. Mother cells of auxiliary cells united with carpogenic branches into definite procarps, the auxiliary cells usually formed only after fertilization, cystocarps not immersed in the frond, gonimoblasts attached to a basal placenta............3. RHODYMENIALES (p. 482).
- *bbb*. Auxiliary cells occurring separately in the thallus, not united with carpogenic branches into procarps, cystocarps usually immersed in the frond, gonimoblasts usually attached to a basal placenta..........................4. CRYPTONEMIALES (p. 515).

Order 1. **Nemalionales** Schmitz.

Nemalioninæ, De Toni, 1897, p. 34.

Gonimoblast formed directly from the fertilized egg itself,[a] consisting of an upright, small, or more or less expanded, branching tuft, whose branches in some cases fuse with neighboring cells of the thallus or with specially formed auxiliary cells.

KEY TO FAMILIES.

Gonimoblast a compressed tuft of segmented branched filaments, whose terminal cells form carpospores, external or immersed, not inclosed by a sterile jacket..1. HELMINTHOCLADIACEÆ (p. 468).

Gonimoblast a widely expanded tuft of segmented branched filaments, some segments fusing with neighboring cells; the apices of these fertile filamentous branches confluent into an hymenium from which the carpospores arise............................2. GELIDIACEÆ (p. 474).

Family HELMINTHOCLADIACEÆ (Harvey) Schmitz.

Nemalionaceæ Howe.

Thallus filamentous, terete, or compressed, variously branched, usually gelatinous, sometimes incrusted with lime; structure conspicuously filamentous, central axis usually present; asexual propagation by monospores, dispores, tetraspores, or polyspores; antheridia scattered or clustered on the apices of short, filamentous branches, often developing from ordinary vegetative cells, each producing one or a few spermatia; carpogonia borne at the apices of short specialized or unspecialized, filamentous branches; the fertilized egg gives rise directly to a tuft of segmented, branched filaments (gonimoblast) whose terminal cells (and sometimes subterminal ones also) form carpospores; sporocarp external or immersed, usually naked, sometimes surrounded by a few sterile filaments;

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[a] Doubt may be thrown on this point by the work of Svedelius (1915), showing the presence of auxiliary cells in Scinaia. The retention of this genus in the Nemalionales would, however, break down the distinction between the Nemalionales and the Gigartinales, necessitating their combination into a single order characterized (?) by the presence or absence of auxiliary cells. It seems, as far as our present knowledge goes, therefore, that Scinaia and other genera having these structures should be transferred to the Gigartinales, and that the Nemalionales should be retained as now understood, including the genera lacking auxiliary cells.

sporangia and sexual organs on the same or different individuals; antheridia and carpogonia on the same or different individuals.

About 110 species, fresh water and marine, in temperate and tropical regions.

Genus **Acrochætium** Nægeli.

Acrochætium, Nægeli, 1861, p. 402.
Trentepohlia, Farlow, 1882, p. 108.
Chantransia, De Toni, 1897, p. 67.

Thallus filamentous, segmented, monosiphonous, irregularly branched, increasing in length by transverse division of the apical cell, branches often terminating in hairs; asexual propagation by monospores, occasionally by dispores, tetraspores, or polyspores, sporangia occurring singly or in tufts, lateral and sessile on the branches or terminal on short ramuli; sexual reproduction by eggs borne in carpogonia, and spermatia; antheridia borne in tufts at the apices of short branches; carpogonia borne singly at the apices of one to three celled branches; sporocarp naked, bearing a tuft of filaments whose terminal cells form carpospores; sporangia and sexual organs borne on the same or different individuals; monœcious or diœcious; sexual reproduction apparently lacking in some species.

About 60 species, marine and fresh water.

This genus has had a varied nomenclature. Originally described as Acrochætium, it has been called Chantransia by many authors. For a time the group, as now reconized, was separated into two genera—the species with sexual fruit being placed under Chantransia and those with sexual fruit unknown being referred to Acrochætium. It is now generally agreed that this distinction is not valid, but there is still disagreement as to the proper name for the genus. As was pointed out by Howe (1914a, p. 83), the name Chantransia has been used for several other forms and is, moreover, a violation of all the codes of nomenclature. The name Acrochætium is therefore to be preferred, both because of its priority and because it is less likely to cause confusion.

Some of the species are distinguished with ease, but others are separated by inconspicuous, apparently intergrading, characters, and are determined with great difficulty. It is often impossible to decide with certainty to what species a single given plant should be referred.

KEY TO SPECIES.

a. Plants growing in hydroids .... 6. *A. infestans* (p. 473).
aa. Plants growing on or in other algæ .... *b*.
  b. Upright filaments arising from an external basal disk .... 7. *A. virgatulum* (p. 473).
  bb. Upright filaments arising in part from an external or internal basal filament .... *c*.
    c. Basal filament entirely internal, original basal cell conspicuous, sporangia, antheridia and carpogonia borne on different plants .... 5. *A. corymbiferum* (p. 473).
    cc. Basal filament mostly external, original basal cell inconspicuous, sporangia, antheridia and carpogonia borne on the same plants .... 4. *A. affine* (p. 471).
  bbb. Upright filaments arising from a single basal cell or from a few secondary basal cells .... *d*.
    d. Plants not visible to naked eye .... 1. *A. parvulum* (p. 470).
    dd. Plants visible to naked eye as a fine velvety fringe or mat .... *e*.
      e. Basal cell pear shaped, penetrating the host to a depth of 12 to 20 mic .... 4. *A. affine* (p. 471).
      ee. Basal cell spherical or nearly so, 12 to 25 mic. in diameter, not conspicuously penetrating the host, usually bearing several upright filaments, branches often elongated and tapering toward apices .... 3. *A. hoytii* (p. 470).
      eee. Basal cell spherical, 5 to 8 mic. in diameter, superficial, usually bearing a single upright filament, branches not greatly elongated, not tapering toward apices .... 2. *A. dufourii* (p. 470).

1. **Acrochætium parvulum** (Kylin) comb. nov. Fig. 25.

Chantransia parvula, Kylin, 1906, p. 124, f. 9.
P. B.-A. No. 1999. (*Chantransia hallandica* var. *parvula* (Kylin) Rosenvinge.)

Plants 70 to 185 mic. tall, usually 100 to 150 mic.; basal cell 7 to 15 mic. in diameter, usually 7 to 10 mic., bearing 1 to 6 erect filaments; cells 4 to 10 mic. in diameter, usually 6 to 7 mic., 1 to 3.5 diameters long, usually 1.5 to 2 diameters; branching frequent, secund or opposite; branches short, tapering, nearly every cell bearing a short apical hair which is frequently pushed to one side and may be shed; sporangia 6 to 9 by 8 to 14 mic., usually 6 to 8 by 12 to 13 mic., usually sessile, sometimes on a one-celled pedicel, frequently opposite; sexual organs borne on the same individuals as the sporangia or lacking.

Scandinavia.

Abundant on *Polysiphonia harveyi*, sea buoy, Beaufort, N. C., July 27, 1909.

This species may be easily distinguished from the others occurring at Beaufort by its habit and its small size. Although all the specimens observed were sterile, the characters of the plants agree so closely with the published descriptions and figure of *Chantransia parvula* Kylin that it seems better to refer it to this species than to describe it as a new one. In the Beaufort specimens there is usually only one erect filament arising from the basal cell, although occasionally as many as four have been observed. It has not previously been reported from any region outside of Scandinavia.

2. **Acrochætium dufourii** Collins. Fig. 26.

Chantransia dufourii, Collins, 1911, p. 187.
Acrochætium dufourii, Collins, P. B.-A. No. 1594.
P. B.-A. Nos. 1594, 2087.

Plants 200 to 600 mic. tall, usually 250 to 350 mic.; basal cell (original spore) 5 to 8 mic. in diameter, bearing 1 to 3 erect filaments; cells 4 to 5 mic. in diameter, 2 to 5 diameters long; branching rather sparse, sometimes opposite or alternate, more commonly secund; branches erect, not very closely set, not tapering at their apices; sporangia 5 to 6 by 7 to 10 mic., sessile or on a one-celled pedicel, on the main filament, or on a branch, usually in secund series; sexual organs unknown.

North Carolina; Bermuda.

Abundant on *Sargassum filipendula*, Fort Macon jetty, Beaufort, N. C., usually in company with *Erythrotrichia carnea* and often with *Gomiotrichum alsidii*, summer and autumn.

This species most nearly resembles *A. hoytii*, from which it is distinguished by its smaller size, its smaller, superficial basal cell, its less frequent branching with consequent more open habit, and its usually less elongated branches not tapering toward the apices. There is usually only one upright filament from the basal cell, but sometimes two or three are observed. Two or three plants resembling *A. dufourii* in other respects have been observed on *Dictyota dichotoma* arising from short, horizontal, external filaments with no evident basal cell. If these plants should be referred to this species it would show a behavior here similar to that found in *A. affine*, where, apparently, the basal cell may form horizontal filaments and may itself become inconspicuous or disappear. In view of the small number of plants observed in this condition, however, the author has been unwilling to change the limits of the species to include these.

This species is not known outside of North America, although, according to Collins (1911), it appears to be the plant of the Mediterranean distributed by Dufour as *Callithamnion lenormandi* in Erbario Crittogamico Italiano, No. 953, but not *C. lenormandi* Suhr, in Kuetzing, 1849a, p. 640.

3. **Acrochætium hoytii** Collins. Figs. 27 and 28.

Acrochætium hoytii, Collins, 1908, p. 134.
Chantransia hoytii, Collins, 1911, p. 186.
P. B.-A. No. 1540.

Plants 0.25 to 1.3 mm. tall, usually 0.5 to 0.65 mm.; basal cell (original spore) 12 to 25 mic. in diameter, spherical or somewhat elongate vertically, then up to 30 mic. long, superficial or slightly embedded in the host, bearing 1 to 4 erect filaments, very rarely forming one or more secondary basal cells; cells of main filaments 5 to 7 mic. in diameter, usually 2 to 4 diameters long; branching rather frequent below, usually rarer above, often secund; ultimate branches usually elongated, often simple or nearly so, usually tapering gradually toward the apices; sporangia lateral on the upper part of the filament and branches, usually on one-celled pedicels, sometimes sessile, usually secund, oblong, about 5 to 6 by 11 to 15 mic.; cystocarps very rare, borne on short pedicels near the base of the branches.

Very abundant on *Dictyota dichotoma* on Fort Macon jetties, Beaufort, N. C., less abundant on Dictyota in harbor, usually unmixed with other algæ, summer and autumn.

Endemic.

This species appears to be related to *A. dufourii* on the one side and to *A. affine* on the other. In fact, these three species seem to form an intergrading group, so that distinctions are frequently very difficult. From *A. dufourii* it is distinguished by its usually larger size, larger, sometimes slightly embedded basal cell, more abundant branching with consequent denser habit, and its usually more elongated branches tapering toward the apices. The germinating spore seems to not merely remain distinct throughout the life of the plant, but to increase to many times its original size, and may send up as many as four erect filaments. It is distinguished from *A. affine* by its smaller size, its smaller and shorter cells, its more nearly spherical and more superficial basal cell, the absence of horizontal filaments, the abundance of sporangia, and the great scarcity of cystocarps. The basal cell usually remains unchanged except for its increase in size, and forms, at most, a few secondary basal cells which do not give rise to upright filaments. The general habit resembles *A. corymbiferum* but it is readily distinguished from that species by the differences in the basal portions of the plants and in the formation of the organs of reproduction. Its habit is sometimes very dense.

Small plants of *A. hoytii* are especially difficult to distinguish from *A. dufourii* since they are often sparsely branched and do not bear elongated, tapering branches. With such plants the principal distinguishing character is the size of the basal cell, but even with this it is not always easy to determine to which of these species a given plant should be referred.

4. **Acrochætium affine** Howe and Hoyt. Pl. CXIX.

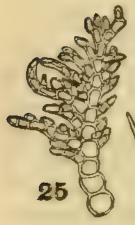
Acrochætium affine, Howe and Hoyt, 1916, p. 118, pl. 15.

Plants 1 to 3.5 mm. tall; basal cell (original spore) subglobose or ellipsoid, mostly 14 to 26 mic. in diameter, finally becoming subpyriform and 20 to 33 mic. high through the development of a subcylindric obtuse or truncate foot penetrating the host for about 10 to 24 mic., the basal cell remaining simple or occasionally developing one or more smaller accessory cells, or sometimes sending out short, creeping, often more or less immersed filaments 2 to 5 cells long, these very rarely forming a small imperfect basal disk, the secondary basal cells often sending up erect filaments; erect primary filaments 1 to 4 (usually 2 to 3) from the primary basal cell, 6 to 14 mic. in diameter, often subdichotomous or subtrichotomous at the distal end of the first cell, erect filaments from secondary basal cells 1 to 4 (when present), commonly more slender, 4 to 8 mic. in diameter, all filaments somewhat rigid below, becoming flexuous above, rather sparingly and irregularly branched, the branching subdichotomous or distinctly lateral, ultimate branches 3 to 5.5 mic. in diameter, mostly elongate-virgate, terminal hairs often present, but rather inconspicuous; cells of filaments cylindric, firm-walled, mostly 3 to 9 times as long as broad; sporangia uncommon, lateral on one-celled pedicels, lateral and sessile, or sometimes terminal on main branches, 18 to 27 mic. by 10 to 18 mic.; antheridia usually close to the procarp, lateral or somewhat terminal, solitary or in groups of 2 to 3; cystocarps abundant, mostly 3 to 8 spored, carpospores 13 to 26 mic. by 8 to 18 mic.; antheridia, cystocarps, and (sometimes at least) sporangia occurring on the same individual.

Abundant on *Dictyota dichotoma* and occasional on *Spyridia filamentosa* and other hosts dredged from the coral reef offshore from Beaufort, N. C., August, 1914.

Endemic.

This species most nearly resembles *A. hoytii*, which is borne on the same host in Beaufort Harbor. From this it differs in its larger size, its larger and longer cells, its more elongated and more embedded basal cell, its occasional formation of horizontal filaments, the infrequent formation of sporangia, and the relatively abundant cystocarps produced on the same plants. Its general habit resembles *A. coymbiferum*, from which it is distinguished by its larger, more persistent, partially embedded basal cell, the upright filaments often arising entirely from this, by the less abundant cystocarps, these, the antheridia, and the sporangia being borne on the same plants, and by the fact that the horizontal filaments, when present, are mostly external. From *A. dufourii* it is distinguished by its larger size, its larger, partially embedded basal cell, its more abundant branching, the branches tapering toward the apices, and by its fairly abundant production of cystocarps.



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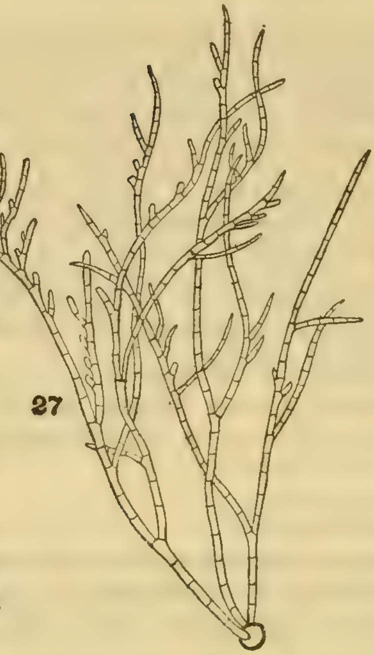

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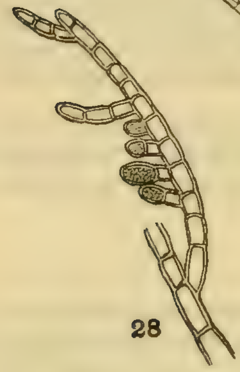

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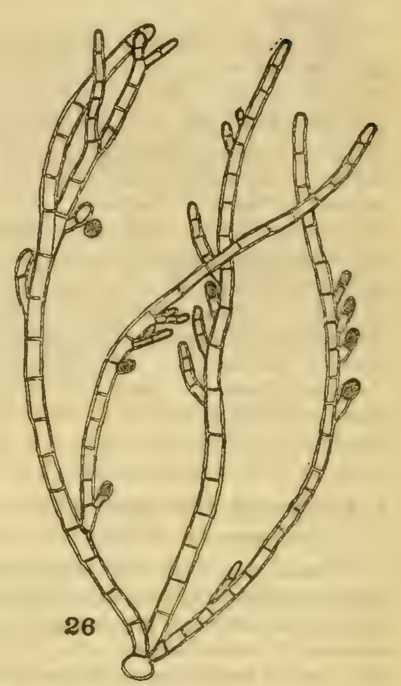

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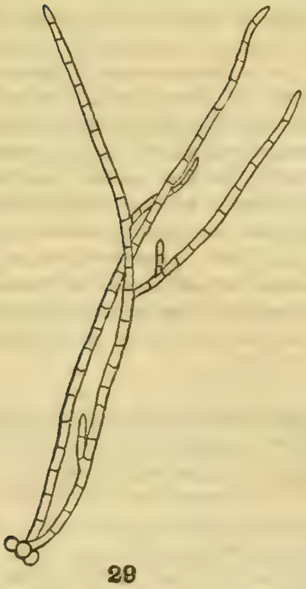

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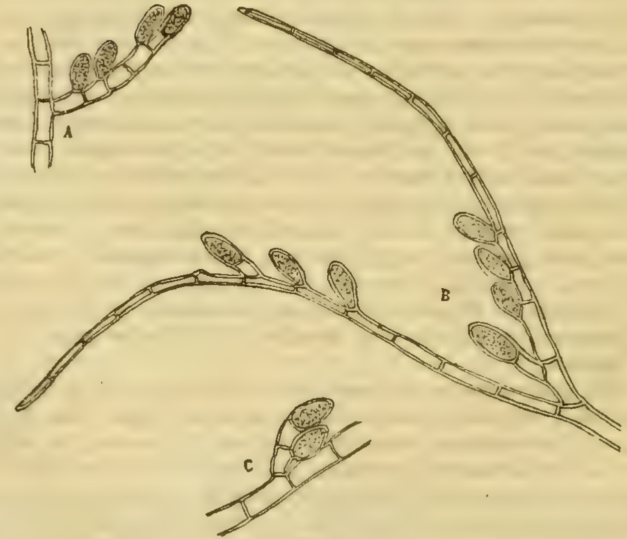

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Fig. 25.—*Acrochætium parvulum*, × 189.

Fig. 26.—*Acrochætium dufourii*, showing monosporangia and spore, drawn from cotype, × 189.

Fig. 27.—*Acrochætium hoytii*, drawn from cotype, × 98.

Fig. 28.—*Acrochætium hoytii*, showing monosporangia, × 189.

Fig. 29.—*Acrochætium virgatulum*, × 98.

Fig. 30.—*Acrochætium virgatulum*, showing monosporangia, × 257.

5. **Acrochætium corymbiferum** (Thuret) Collins and Hervey.

Chantransia corymbifera, Thuret, in Le Jolis, 1863, p. 107.
Chantransia corymbifera, De Toni, 1897, p. 69.
Acrochætium corymbiferum, Collins and Hervey, 1917, p. 97.
P. B.-A. Nos. 1040, 1880 (*Chantransia corymbifera*); not No. 192.

Plants 2 to 3 mm. tall; basal cell (original spore) 12 to 15 mic. in diameter, sending down into the host a branching filament about the size of the erect filament but more irregular and contorted; erect filaments arising from the basal cell and the secondary internal filament; cells 8 to 16 mic. in diameter, 3 to 10 diameters long; branches few below, more abundant above, alternate or somewhat secund, virgate, sparingly branched; sporangia sessile or shortly pedicellate near the bases of the branches; cystocarps forming dense, hemispherical clusters of naked spores near the bases of the branches; antheridia forming small, dense, short-pedicellate clusters at various points on the branches; sporangia, cystocarps, and antheridia produced on different plants.

California; Bermuda; England; Atlantic coast of France.

Very abundant on one plant of *Dasya pedicellata* growing in harbor, Beaufort, N. C., May, 1907.

This species has not previously been reported from our coast. While found on only one plant, it was probably more abundant, as it was completely hidden by the hairs of its host. No sporangia have been observed here. The habit of this species resembles that of *A. hoytii* (figs. 27 and 28), but it is easily distinguished from the latter by its internal basal filaments and its abundant cystocarps. From *A. affine* it is distinguished by its smaller, more superficial basal cell, by its abundant internal horizontal filaments, and by its production of sporangia, antheridia, and cystocarps on different plants.

6. **Acrochætium infestans** Howe and Hoyt. Pl. CXVIII.

Acrochætium infestans, Howe and Hoyt, 1916, p. 116, pl. 14.

Plants consisting of extensive branched basal filaments growing in hydroids and sending out more or less numerous external filaments; interior filaments tortuous, intricate, serpentine, or labyrinthine, or sometimes straight for considerable distances, mostly 2 to 5.5 mic. in diameter, the branching very irregular, lateral, subdichotomous, or very rarely opposite, commonly divaricate from near the middle of a cell, the branches often somewhat curved, the interior cells mostly 12 to 60 mic. long, 3 to 18 times as long as broad, commonly curved or contorted and of irregular or fluctuating diameter, sometimes expanded to form, with cells of adjacent filaments, a subparenchymatous layer composed of irregularly shaped cells 9 to 13 mic. wide and 7 to 14.5 mic. long, the terminal cells of branches often enlarged, somewhat hooked at the ends, irregularly club-shaped, or somewhat forking, sometimes attaining a diameter of 7 to 8 mic.; external filaments up to 90 mic. tall (or 230 mic., including hairs), the simpler ones consisting of a single pedicel cell bearing 1 to 3 sporangia (or, very rarely, the exserted sporangium sessile on an internal filament), the larger ones showing 1 to 9 short, 1 to 3 celled, rarely secund branches, the cells 4.5 to 6.5 mic. in diameter, 1 to 2 diameters long; very slender, colorless hairs commonly present on the larger external filaments, flexuous and attaining a length of 125 to 170 mic.; sporangia terminal or lateral, solitary or in groups of two or three, ovoid or ellipsoid, 6 to 8.5 by 10 to 14 mic.; sexual reproduction unknown.

Abundant on *Clytia minuta* (and other hydroids?) growing on *Dictyota dichotoma* and *Sargassum filipendula* dredged from coral reef offshore, Beaufort, N. C., August 11, 1914.

Endemic.

The hydroids acting as hosts for this alga were usually not obtained in sufficiently good condition to warrant determination. Three of the best of these, kindly examined by Prof. C. C. Nutting, were identified as (1) *Clytia minuta*, (2) probably *Plumularia sp.*, (3) *Campanularian hydroid*. The internal filaments grow within the ectosarc and are abundant throughout the stalks of the hydroids, occurring to a less extent in the rhizomes and hydranths. Various stages, from the ungerminated spore to extensive networks of filaments, have been observed.

7. **Acrochætium virgatulum** (Harvey) Bornet. Figs. 29 and 30.

Callithamnion virgatulum, Harvey, in Hooker, 1833, p. 349.
Callithamnion virgatulum, Harvey, 1853, p. 243.
Trentepohlia virgatula, Farlow, 1882, p. 109, pl. 10 ,f. 3.
Chantransia virgatula, De Toni, 1897, p. 69.
Acrochætium virgatulum, Bornet, 1904, p. XXII.
Acrochætium virgatulum, Collins, 1906, p. 193.
A. A. B. Ex. No. 157 (*Chantransia virgatula* f. *luxurians*).
P. B.-A. Nos. 741 (*Chantransia virgatula* f. *tenuissima*). 1594.

Plants 0.8 to 2.6 mm. tall, usually 1.5 to 2 mm.; one to many filaments arising from a basal disk; cells 7 to 14 mic. in diameter below, 4 to 10 mic. in diameter above, 3 to 5 diameters long below, 4 to 6 diameters long above; filaments long and straight with rather few long, straight, erect branches, usually terminating in a very slender hair; short ramuli, mostly 1 to 3 celled, abundant, scattered, opposite or in short secund series, bearing either hairs or terminal sporangia; sporangia also sessile on the branches, occupying the places of ramuli, 10 to 12 by 20 to 24 mic.; sexual organs unknown.

Temperate North Atlantic.

Fairly abundant on *Gracilaria multipartita*, *G. confervoides*, *Agardhiella tenera*, *Petalonia fascia*, and *Padina vickersiæ* on Fort Macon and Shackleford jetties and in harbor, Beaufort, N. C., throughout the year.

This species may be distinguished by its basal disk bearing one or more erect filaments and its long, straight branches, which are often subsimple. In the typical form the branches bear short ramuli or spores on nearly every cell, and numerous hairs, the hairs not being formed by a gradual tapering of the branch but appearing abruptly at the apex of a cell of about the same size as the preceding ones. But in some forms the branches are long and tapering, without hairs and with infrequent branching.

In the Beaufort specimens hairs are lacking and short ramuli are infrequent. In some specimens the branches taper gradually to the apices, in some they taper slightly, while in some specimens, similar to the preceding ones in other respects, they are nearly of uniform diameter throughout. In the majority of cases the filaments are long, straight, and sparingly branched, sometimes being entirely simple; sporangia are borne in short secund series on the main branches, usually being lateral and sessile, less often terminating longer or shorter ramuli. In these respects the Beaufort specimens resemble f. *tenuissima* Collins (1906, p. 194). From this they differ, however, in that the diameter of the filaments is greater and the basal disk is larger, sometimes almost forming a continuous layer of considerable extent and approaching in this respect f. *luxurians* Collins.

This is the southern limit reported for the species on our coast, but it probably extends farther.

Acrochætium sp.

Plants differing from all the above-mentioned species and not certainly referable to any described species were found in abundance on *Sargassum filipendula*, *Agardhiella tenera*, and, in less amount, on *Gracilaria confervoides* dredged from the coral reef offshore, July and August, 1915. In view, however, of our ignorance of the variation of plants belonging to this genus when growing on different hosts or under different conditions it has not seemed wise to describe these as a new species.

Of the seven identified species of this genus found at Beaufort five have been observed on only one host—*A. hoytii* and *A. affine* on *Dictyota dictotoma*, *A. parvulum* on *Polysiphonia harveyi*, *A. corymbiferum* on *Dasya pedicellata*, and *A. infestans* on hydroids. *A. dufourii* has been observed on *Sargassum filipendula* and apparently also on *Dictyota dichotoma*, while *A. virgatulum* has been found on five species of algæ, but not on the same host occupied by any of the other species of Acrochætium.

Family 2. GELIDIACEÆ (Kuetzing) Schmitz.

Frond terete or compressed, usually laterally branched, with fairly evident filamentous structure and usually thick and firm texture, traversed by a segmented axial tube (often indistinct in the older parts), from which arise branched lateral filaments composing the cortex; tetrasporangia zonately, cruciately, or triangularly divided, grouped in special portions of the thallus or scattered in the outer rind; antheridia occurring in a more or less widely expanded layer over the surface of special portions of the thallus or forming small, scattered tufts arising from the cortical filaments; carpogonia borne beneath the surface on the cortical filaments or laterally on the central axis, often occurring in special fertile portions of the thallus; the fertilized eggs give rise directly (often after fusion with one or more neighboring—quasi auxiliary—cells) to gonimoblasts composed of much-branched, expanded filaments; ends of these fertile filamentous branches confluent into an hymenium on the apices of which the carpospores are borne singly or, rarely, in short chains.

About 90 species, all marine, mostly in warm and temperate seas.

Genus **Gelidium** Lamouroux.

Gelidium, Lamouroux, 1813, p. 40.

Frond terete or flattened, pinnately decompound, of tough, firm texture, with thick dense rind; central axis composed of a segmented, longitudinal filament, from which arise numerous obliquely longitudinal filaments verticillately arranged and densely coalescent into a proper cortex, outer rind cellular, with larger cells toward the center, smaller ones toward the periphery; central axis with distinct apical cell. Tetrasporangia formed in sori immersed in local swellings on both sides of the thallus below the apices of ordinary pinnæ, rotund, cruciately divided; cystocarps immersed in swollen portions below the apices of ordinary pinnæ, usually divided by a longitudinal partition into two chambers, one on each side of the flattened thallus, each chamber communicating with the exterior by a separate pore, carpospores obovate arising singly from the hymenial layer, pericarp raised up from the hymenial layer but joined with it by numerous simple filaments, antheridia occurring in superficial patches; tetrasporangia and cystocarps occurring on separate plants.

About 25 species recognized, many separated by inconspicuous, probably doubtful, characters; in warm and temperate seas.

KEY TO SPECIES.

Upright branches 1 to 2 cm. tall or less, comparatively thick, flattened, much branched..... ....1. *G. coerulescens* (p. 475).
Upright branches 2 to 3.5 cm. tall, slender, subterete, sparsely branched.........2. *G. crinale* (p. 475).

1. **Gelidium cœrulescens** Kuetzing. Pl. XCV, fig. 1.

Gelidium cœrulescens, Kuetzing, 1868, Bd. 18, p. 19, pl. 56, f. 2.

Thallus erect, flattened, arising from a fine, filiform, creeping base, 1 to 2 cm. tall, 0.3 to 0.5 mm. wide in widest portion; branching decompound, distichous from the margins, sparse below, more or less dense above; texture fleshy gelatinous; color, dark purplish brown.

West Indies; New Caledonia.

Very abundant, forming low, dense masses on jetties, walls, shells, and stones at Fort Macon, Beaufort, N. C., and along town front from about 10 to 70 cm. above low tide line, April to October, probably throughout the year.

This species was identified by Mr. Collins on the basis of a Guadeloupe specimen determined by Crouan, and it may perhaps be questioned whether it is really the species described by Kuetzing.

2. **Gelidium crinale** (Turner) J. Agardh. Pl. XCV, fig. 2.

Fucus crinalis, Turner, 1808, pl. 198.
Gelidium crinale, J. Agardh, 1876, p. 546.
Gelidium crinale, Farlow, 1882, p. 158.
Gelidium crinale, De Toni, 1897, p. 146.
P. B.-A. Nos. 195, 2089.

Primary frond decumbent, about 0.5 mm. in diameter, giving off erect branches, terete or sometimes slightly flattened, slender, 2 to 7 cm. tall, sparingly branched, sometimes almost simple; color purple or yellowish brown.

Warm and temperate waters generally, occurring on our coast from Maine to Florida.

Fairly abundant between tide lines on Fort Macon jetties, Beaufort, N. C., April to August, 1908, probably occurs throughout the year, abundant on submerged shells in Newport River near "Green Rock," August, 1906; abundant in Core Sound near Leckly's Island July, 1908; fairly abundant in Pamlico Sound on shells and posts between tide lines, Ocracoke, N. C., August, 1907; one specimen on submerged shell, Pawleys Island, near Georgetown, S. C., August, 1909.

This species varies considerably in the size of the clusters, the height of the upright branches, the amount of branching, and the amount of flattening. The clusters may be dense or loose, the upright branches may be 2 to 7 cm. tall; branching is usually sparse and irregular, but may be fairly regularly pinnate at the apices, or the fronds may be entirely unbranched; they are usually almost terete, but may show slight, distinct flattening.

The two species occurring in this region can usually be easily distinguished as follows: *G. cœrulescens* forms dense mats, has a dense, compact habit, with the upright branches short (8 to 15 mm. tall), flattened, comparatively wide, much branched in a fairly regular, decompound manner; *G. crinale* usually occurs in sparse clusters, has a slender, open habit, with the upright branches comparatively long (2 to 3 cm.), rounded or very slightly flattened, slender, usually sparsely and irregularly branched, sometimes simple, sometimes fairly regularly pinnate.

Gelidium sp. indet.

A single indeterminable fragment from Bogue Beach, Beaufort, N. C., September, 1905, is 4 cm. long, about 0.5 mm. wide, and 0.1 mm. thick, narrow, flattened, sparsely pinnate, pink. This may be a battered specimen of *G. corneum* or may be a portion of one of the larger, more tropical species.

Order 2. **Gigartinales** Schmitz.

Gigartininæ, De Toni, 1897, p. 169.

Carpogonial filaments and auxiliary cells usually occurring together in pairs, forming definite procarps, sometimes occurring singly in the thallus. Cystocarps usually immersed in the frond. Gonimoblast arising from an auxiliary cell after the fertilized egg has fused with this by means of a usually short carpogonial process, not attached to a basal placenta.

KEY TO FAMILIES.

Gonimoblast consisting of a richly branched tuft whose branches are distributed without order within the inclosing structures; tetrasporangia usually cruciately divided . 1. GIGARTINACEÆ (p. 476).

Gonimoblast divided into several lobes radiating inwardly in all directions; tetrasporangia zonately divided..2. RHODOPHYLLIDACEÆ (p. 478).

Family 1. GIGARTINACEÆ Schmitz.

Frond terete, flattened, or foliaceous; dichotomously or pinnately branched, sometimes simple or irregularly lobate; structure cellular or filamentous, usually plainly fan-like at apices; tetrasporangia scattered over the frond in the outer cortex, or grouped in sori and immersed in the thallus, or borne in special protuberances (nemathecia), usually cruciately, sometimes zonately, divided; antheridia usually in patches more or less widely distributed over the surface of the thallus, sometimes in flasklike cavities sunk in the outer cortex and opening to the exterior; carpogonia usually numerous on the fertile portions of the thallus, usually produced singly on a three-celled carpogenic branch associated with an auxiliary cell into a definite procarp; the fertilized egg fuses with the auxiliary cell by a short process; the latter then gives rise to the gonimoblast, consisting of a tuft of filaments richly branched in all directions; the branches of this tuft are themselves richly branched and interwoven to form a structure of fertile and sterile filaments almost without order; the apical cells of the fertile filaments (and sometimes subapical ones also) form carpospores which lie in groups usually without order; fruits often inclosed by a sterile jacket; these cystocarps usually occur scattered over the thallus, immersed or more or less prominent on one or both sides, and communicate with the exterior by one or more often inconspicuous pores.

About 275 species, all marine, especially in cold and temperate seas.

KEY TO GENERA.

Frond terete, dichotomous, cartilaginous .... 1. Gymnogongrus (p. 477).
Frond parasitic, appearing from the exterior as a cushionlike nemathecium on Gymnogongrus. .... 2. Actinococcus (p. 477).

Genus 1. **Gymnogongrus** Martins.

Gymnogongrus, Martins, 1833a, p. 27.

Frond terete or flattened, repeatedly dichotomous, often also with more or less numerous lateral branches, of fleshy-leathery or horny consistency; tetrasporangia unknown; procarps borne on fertile upper segments of the frond in flattened prominences; cystocarps immersed in the frond, more or less prominent on one or both sides; containing a compound "nucleus" bearing numerous rounded carpospores without order among sterile filaments; fruit entirely inclosed; at length freed by the formation of one or more pores.

About 35 species, widely distributed, especially in warm and temperate seas.

Gymnogongrus griffithsiæ (Turner) Martins. Pl. XCV, fig. 3.

Fucus griffithsiæ, Turner, 1808, pl. 37.
Gymnogongrus griffithsiæ, Martins, 1833, p. 27.
Gymnogongrus griffithsiæ, De Toni, 1897, p. 242.
P. B.-A. No. 239.

Frond terete or slightly compressed, 1 to 5 cm. tall, slender, about 1 mm. in diameter, several stems arising from a rootlike callus, branching dense or sparse, usually regularly dichotomous, often polychotomous and with irregular pinnate branches, main branches unbranched below, richly branched above, forming dense tufts at the apices; substance cartilaginous, color dark purple, becoming blackish when dry.

North Atlantic and Pacific Oceans; Mediterranean Sea.

Abundant on Fort Macon jetties, Beaufort, N. C., about 15 cm. above to 15 cm. below low water, throughout the year; occasional on Bogue Beach and in harbor.

Specimens from different localities vary in height and diameter of fronds, amount of branching, and amount of flattening. Those from this region are fairly uniform, being 2.5 to 3.5 cm. tall, and comparatively thick, rigid, and terete.

Genus 2. **Actinococcus** Kuetzing.

Actinococcus, Kuetzing, 1843, p. 177.

Thallus parasitic, minute, living within the tissues of other Florideæ, and forming fruiting cushions on the surface of the host plant; vegetative portion consisting of filaments penetrating the host and winding about among the cells of the frond; fruiting cushions more or less hemispherical or flattened-convex, strongly attached to the host, composed of fanlike radiating filaments, with cells gradually decreasing in size toward the periphery; tetrasporangia numerous in the cortical layer of the nematheciform cushion, moniliform serrate, cruciately divided, arising from the transformation of the cells (usually with the exception of the 2 to 4 apical ones) of the radiating filaments; antheridia and cystocarps unknown.

Four to five species recognized, occurring on different genera of algæ, mostly on species of Gymnogongrus.

The members of this genus were originally taken for the tetrasporic fruits of their hosts. "Several genera of this character have been described. It is a curious fact that in each case the parasite has tetrasporic fruit of the character appropriate to the host, while the host appears to have lost the capacity for producing tetraspores, and is propagated either by cystocarps or only vegetatively." (Collins, 1901a, p. 134.)

Antheridia and cystocarps have been described for one species of Actinococcus, but this observation seems founded on insufficient evidence.

Actinococcus aggregatus Schmitz.

Actinococcus aggregatus, Schmitz, 1893, p. 385, pl. 7, f. 8.
Actinococcus aggregatus, De Toni, 1897, p. 259.
P. B.-A. No. 786.

Parasitic on *Gymnogongrus griffithsiæ*, the vegetative portion occurring as fine filaments between the cells of the host; fruit appearing as a protuberant pad on the surface of the host, minute, about 1 mm. wide, rounded, flattened convex, single or several approximate; tetrasporangia cruciately divided, often imperfectly septate.

North Atlantic and Pacific; Mediterranean Sea.

On about one-fourth of the specimens of *Gymnogongrus griffithsiæ*, Fort Macon jetties, Beaufort N. C.

Family 2. RHODOPHYLLIDACEÆ Schmitz.

Frond terte, flattened, or foliaceous, dichotomously or laterally branched; structure cellular or cellular-filamentous, seldom filamentous; tetrasporangia usually scattered over the thallus surface, sometimes collected into numerous sori, sunk in the outer cortex, which is often thickened to form nematheciumlike structures, nearly always zonately divided; antheridia usually in patches more or less widely distributed over the surface; carpogonia numerous on the fertile portions of the thallus, sometimes distant from the auxiliary cells and, after fertilization, fusing with one of these by a filament; auxiliary cells usually less numerous than the carpogonia, sometimes not formed until after fertilization; cystocarps scattered over the thallus, often situated at the edges, immersed or more or less prominent, usually provided with a conspicuous pore; gonimoblast suspended from an upper wall of the cystocarpic cavity, divided into several lobes radiating in all directions, forming spores in the apical cells of the filaments and sometimes in the subapical ones also.

About 110 species, all marine, in all parts of the world.

KEY TO GENERA.

a. Auxiliary cell forms on a protuberance bearing filamentous tufts, which radiate in every direction and branch outward fasciculately .... *b*.
  b. Frond terete, radially branched, subtubular above, of cellular-filamentous structure .... 1. Agardhiella (p. 478).
  bb. Frond foliaceous, usually pinnately or furcately divided, with numerous warts or papillæ on the surface and margins .... 2. Meristotheca (p. 479).
aa. Auxiliary cell extends a thick projection into the cystocarpic cavity and bears at its apex numerous tufts of filaments .... *c*.
  c. Frond terete or slightly flattened, laxly tubular, sometimes caulescent and solid below .... 3. Rhabdonia (p. 480).
  cc. Frond terete or flattened, structure dense, rigid, furnished with short, acute or obtuse, simple or branched papillæ .... 4. Eucheuma (p. 481).

Genus 1. Agardhiella Schmitz.

Agardhiella, Schmitz, 1889, p. 441 (7).

Frond terete, branched on all sides, subtubular and rather lax above, structure cellular-filamentous, medullary filaments reticulately anastomosing, more or less lax, cortex large celled within, very small celled without; tetrasporangia scattered over the surface, zonately divided; auxiliary cells not united with the carpogonia, scattered throughout the frond; cystocarps scattered through the frond, entirely immersed or slightly prominent, "nucleus" transversely oval or almost spherical, situated in the medullary layer or in the inner lax part of the cortex, unilaterally attached to the outer cortex, inclosed by a dense, subdiscrete filamentous pericarp with a broad cellular center and radiating, tufted, expanded filaments, on which the carpospores are borne singly at the apices, the center of the "nucleus" joined to the pericarp by single radial strands of sterile filaments, communicating with the exterior by an apical pore.

Four to five species on Atlantic and Pacific coasts and in Australian regions.

Agardhiella tenera (J. Agardh) Schmitz. Pl. XCVI.

Gigartina tenera, J. Agardh, 1841, p. 18.
Rhabdonia tenera, J. Agardh, 1851, p. 354.
Solieria chordalis, Harvey, 1853, p. 121, pl. 23a.
Rhabdonia tenera, Farlow, 1882, p. 159, pl. 14, f. 2.
Agardhiella tenera, Schmitz, 1889, p. 441 (7).
Agardhiella tenera, De Toni, 1897, p. 322.
P. B.-A. Nos. 138 (*Rhabdonia tenera*) (?), 333 (*Agardhiella coulteri*) (?), 539, 1396 (?), 2143.

Frond filiform, 4 to 45 cm. tall, 0.5 to 4 mm. in diameter; decompoundly much branched, branches subalternately virgate, usually going out from all sides, sometimes secund, cylindrical, constricted at the base, gradually tapering toward the apex, bearing numerous linear, fusiform branchlets; tetrasporangia scattered through the cortex of unaltered branches zonately divided; cystocarps borne on separate plants immersed in slightly swollen branches, rather prominent on one side; substance when young is very delicate, when older is rather firm; color red to purple.

Warm and temperate Atlantic and Pacific coasts of America.

Abundant in winter and spring, occasional in summer and autumn, 15 to 30 cm. below low water, in harbor and on jetties, Beaufort, N. C., many slender plants dredged from the coral reef, August, 1914 and 1915.

The species varies greatly in habit, some specimens bearing only a few large branches, while others bear many fine small ones. It is not likely to be mistaken for any other species occurring in this region except *Eucheuma gelidium;* from the latter it is distinguished by its more open habit, with longer, more slender branches, and by its more delicate texture. It here reaches its greatest luxuriance from December to June, attaining at that time a height of 30 cm. and fruiting abundantly. Specimens collected during the summer and autumn are often much battered, although an occasional vigorous fruiting plant may be found during this period.

Yendo (1914) has suggested that many American specimens which have been referred to this species should be placed under *Rhabdonia robusta* (Grev.) J. Ag. As the determination of this point would require more study than it has been possible to give the matter, the author has followed current usage in referring all the plants to *A. tenera*. This has seemed more proper in that, while some of the plants [notably those dredged from the coral reef in 1914 and 1915 (Plate XCVI, fig. 2), in which the internal filaments were lacking] differed from others in appearance, none of them seemed to agree entirely with the descriptions of *R. robusta*.

Börgesen (1919, pp. 361–365) has given a good description, with figures, of the development of the cystocarp of this species.

Genus 2. **Meristotheca** Agardh.

Meristotheca, Agardh, in J. Agardh, 1871, p. 36.

Frond flat, more or less richly furcately or pinnately (usually irregularly) divided sometimes proliferous from the margins, usually with numerous warts or papillæ arising from the margins and surface; structure cellular-filamentous, hollow, the cavity traversed by numerous filaments, cortex composed of large, rounded cells within, becoming smaller toward the surface, tetrasporangia scattered over the surface among the superficial cells of the cortex, zonately divided; cystocarps situated in the warts and papillæ or embedded in the thallus, more or less prominent, "nucleus" with a filamentous-cellular center and peripheral, radial paniculate tufts of filaments bearing carpospores usually singly at their apices, pericarp thick, dense, joined to the center of the "nucleus" by numerous sterile strands of filaments.

About six species, mostly in the Indian Ocean.

Meristotheca duchassaingii Agardh. Figs. 31 and 32; Pl. XCVII.

Meristotheca duchassaingii, Agardh, in J. Agardh, 1871, p. 37.
Meristotheca ? duchassaingii, De Toni, 1897, p. 330.
P. B.-A. Nos. 884, 1596.

Frond flat, expanded, thick, gelatinous, usually subpalmately laciniate, sometimes simple, sometimes with marginal proliferations, surface and margins of female plants beset with numerous short, simple, or branched papillæ in which the cystocarps are borne, surface of tetrasporic plants smooth or slightly roughened, but not bearing papillæ; tetrasporangia zonately divided; color deep rose.

Florida; West Indies.

Occasionally abundant after storms, Bogue Beach, Beaufort, N. C., two small plants dredged from coral reef offshore, August, 1915.

This species has been observed here from only August to October, but has been collected at points farther south from February to April and may be expected here during any month. It is not known where the plants thrown up on our shores have grown. No specimens were found on the coral reef off Beaufort in May, 1907, or in August, 1914. It seems probable that these specimens grew on submerged coral reefs offshore from Beaufort or south of this region.

This is the northern known limit of the species and of the genus.

As was noted by Collins (P. B.-A. No. 1596), the tetrasporangia are divided zonately as in other species of the genus, not cruciately, as figured by Agardh.

Genus 3. **Rhabdonia** Harvey.

Rhabdonia, Harvey, in Hooker and Harvey, 1847, p. 408.

Frond rather terete, sometimes slightly flattened, usually branched on all sides, more or less laxly tubular, sometimes caulescent and thick below, medullary region traversed by longitudinal, branched, anastomosing filaments, cortex composed of rounded angular cells becoming smaller toward the surface; tetrasporangia scattered over the frond among the superficial cells of the cortex, zonately divided; carpogonia occurring singly, immersed in the cortical layer, usually numerous on the fruiting portions of the thallus, auxiliary cells less numerous, usually not conspicuous before fertilization, usually situated more or less near to the carpogonia and, after union with a process from a fertilized carpogonium, usually fusing with neighboring cells; gonimoblast developed toward the interior of the thallus, forming tufts of filaments radiating in all directions; cystocarps scattered in the branches, immersed, rather prominent, with tufts of branched, spore-bearing filaments radiating from a large central cell intermixed with sterile filaments, inclosed by a thick filamentous pericarp, communicating with the exterior by a pore; carpospores single or in pairs in the terminal segments of the filaments, often germinating within the cystocarp.

About 15 species, principally in Australian regions.

Rhabdonia ramosissima (Harvey) J. Agardh. Pl. XCVIII, fig. 1.

Chrysymenia ramosissima, Harvey, 1853, p. 190, pl. 30 B.
Rhabdonia ramosissima, J. Agardh, 1876, p. 593.
Rhabdonia ramosissima, De Toni, 1897, p. 363.
P. B.-A. No. 993.

Frond rather compressed, more or less cylindrical above, decompound, usually much branched, 6 to 45 cm. tall, main axis 2 to 15 mm. wide, medullary layer very lax, branches alternate, spreading, subdistichously arranged, tapering toward base and apex, long and short ones intermixed, branchlets very slender, somewhat spiny; cystocarps immersed in the frond, inconspicuous; color light, rosy red; brownish when dry.

Florida; West Indies.

One specimen August, 1903, one specimen September, 1904, Bogue Beach, Beaufort, N. C.

Specimens vary greatly in the width of the main axis, the amount of flattening, and the amount of branching, the habit may be loose or very dense. The Beaufort specimens are narrower and less branched than the majority of specimens from Florida, but seem quite surely to belong to this species. They are readily distinguished from other species occurring here by their slightly flattened main axis bearing long and short branches without order in two rows from the lateral margins.

This is the northern known limit of the species and of the genus. It seems probable that the specimens found here were brought from Florida by the Gulf Stream, although they may have grown on the coral reefs offshore. The species is entirely American, the type being from Key West, Fla.

Genus 4. **Eucheuma** J. Agardh.

Eucheuma, J. Agardh, 1847, p. 16.

Frond terete or flattened, radially or distichously branched, more or less beset with short, simple or branched, sharp or blunt papillæ; medullary region composed of densely crowded anastomosing filaments, cortex dense, composed of fairly large cells within, becoming smaller toward the surface; tetrasporangia scattered among the superficial cells of the cortex, zonately divided; cystocarps immersed in the cortex, prominent, usually in papillæ, sometimes on the thallus itself, having a large, almost spherical central cell from whose surface arise numerous crowded radiating tufts of richly branched spore-bearing filaments separated by strands of sterile filaments running from the central cell to the dense inclosing pericarp, communicating with the exterior by a pore; carpospores borne singly in the terminal segments of the fertile filaments.

About 15 species, in warm seas, especially in the Indian Ocean.

Eucheuma gelidium J. Agardh. Pl. XCVIII, fig. 2.

Eucheuma gelidium, J. Agardh, 1852, p. 627.
Eucheuma gelidium, De Toni, 1897, p. 372.
P. B.-A. Nos. 541, 2184.

Frond ancipitate compressed, pinnately decompound from the margins, 5 to 13 cm. tall, 3 to 5 mm. wide, bearing numerous short, simple or branched, spinelike papillæ, possessed below of few elongated pinnæ, with smaller tooth-shaped ones interspersed, branched above into a dense corymb; pinnæ distichous, flattened, emitting below abbreviated, little-divided, spine-shaped pinnules, in the upper part longer ones divaricately much branched; substance fleshy-cartilaginous, rather rigid; color dirty reddish.

Florida; West Indies; Barbados.

One battered specimen, Bogue Beach, Beaufort, N. C., August, 1904; several specimens, Fort Macon jetty, Beaufort, N. C., July, 1907; rather abundant on jetties, Ocracoke, N. C., August, 1907.

This species can be distinguished from *Agardhiella tenera*, which it most nearly resembles, by its coarser, firmer texture, its denser branching with development of numerous irregular spinelike branches. In section *E. gelidium* has a denser structure, the central (medullary) layer of anastomosing filaments is more developed, and the cortical layer is thicker and is more distinctly composed of short filaments rather than single cells. The specimens from Ocracoke are often in whole or in part rather fine and slender, but are comparatively rigid. In all the specimens from this region the development of spinelike branches is less marked than is usual, although they agree with this species in other respects.

This is the northern limit of the genus on our coast.

Order 3. **Rhodymeniales** Schmitz.

Rhodymeninæ, De Toni, 1900, p. 387.

Carpogonial filaments and mother cells of the auxiliary cells occurring together in pairs, nearly always united into definite procarps, the auxiliary cells usually cut off only after fertilization. Gonimoblast arising from an auxiliary cell after the fertilized egg has fused with this by means of a short carpogonial process, attached to a basal placenta, cystocarps not completely immersed in the frond.

KEY TO FAMILIES.

a. Gonimoblast somewhat immersed in the thallus, filaments radiating from their point of attachment on a median, thickened placenta within the fruit-bearing cavity, pericarp thick, perforated at the apex.......*b.*

- *b.* Gonimoblast much branched, densely crowded and confluent, usually hemispherical-convex, carpospores borne at the apices of the branches singly or in chains; tetrasporangia cruciately or zonately divided.......1. SPHAEROCOCCACEÆ (p. 482).
- *bb.* Gonimoblast divided into several lobes successively developed, nearly all cells of the lobes forming spores; tetrasporangia nearly always cruciately divided.......2. RHODYMENIACEÆ (p. 487).

aa. Gonimoblast sessile in the thallus, formed within the fruit-bearing cavity, covered by the cortex of the thallus with a perforation at the apex.......*c.*

- *c.* Procarp situated in the median layer of the thallus, gonimoblast attached to the median thickened placenta, gonimolobes usually indistinctly formed, carpospores borne at the apices of the fertile branches singly or in chains; tetrasporangia triangularly divided.......3. DELESSERIACEÆ (p. 493).

aaa. Gonimoblast attached to the thallus by means of a pedicel or broad base, entirely external or somewhat inclosed by the cortex in various ways.......*d.*

- *d.* Cystocarps attached to the thallus by means of a broad base or a short pedicel, gonimoblast attached by a large fusion, central cell within a pericarp perforated at the apex, carpospores large, single in the apices of the fertile branches, less often in chains; tetrasporangia triangularly divided.......4. RHODOMELACEÆ (p. 496).
- *dd.* Cystocarps entirely external or inclosed by the cortex, naked (without pericarp) or more or less loosely enwrapped by their own branches, gonimoblasts single or more often in pairs, usually divided into several lobes, carpospores formed from nearly every cell of the fertile branches; tetrasporangia triangularly or cruciately divided.......5. CERAMIACEÆ (p. 509).

Family 1. SPHÆROCOCCACEÆ (Dumort) Schmitz.

Thallus terete or flattened, dichotomously or laterally branched, structure cellular or cellular filamentous; tetrasporangia situated in the cortical layer, scattered over the surface of the thallus or in nematheciumlike portions, usually zonately, less often cruciately divided; antheridia variously formed; carpogonia usually numerous on the fertile portions of the thallus, apparently closely associated with the cells which, after fertilization, give rise to the auxiliary cells; cystocarps rather prominent, sometimes formed in special branches and then supported by a quasi short stalk, pericarp often thick, usually provided with an apical pore, often joined to the "nucleus" by sterile strands, gonimoblast arising from the base of the fruit, richly branched, densely crowded and confluent, usually hemispherical-convex, forming spores singly or in chains at the apices of the fertile filaments.

About 150 species in warm and temperate seas, especially in Australian regions.

KEY TO GENERA.

Cystocarps not formed in special branches; gonimoblast composed of several coalescent tufts of branches, rather lax, the apices of the branches unequally extended; tetrasporangia cruciately divided..1. Gracilaria (p. 483).

Cystocarps not formed in special branches; cavity of the sporocarp traversed by a lax net from the threads of which arise numerous glomeruli of spore-bearing filaments; tetrasporangia zonately divided..2. Hypnea (p. 485).

Genus 1. **Gracilaria** Greville.

Gracilaria, Greville, 1830, p. 121.

Frond terete or flattened, dichotomously or laterally branched, structure densely cellular, inner cells large, outer ones smaller, cortical ones minute, sometimes developed into vertical filaments; tetrasporangia scattered over the surface among the cortical cells, cruciately divided; antheridia scattered over the branches, in small, flask-shaped cavities opening to the exterior by a pore; cystocarps scattered over the thallus, prominent, hemispherical, pericarp thick, usually free (not joined to the "nucleus" by sterile strands), composed of outwardly radiating rows of cells, finally opening by an apical pore; "nucleus" hemispherical-convex, arising from the base of the fruit, bearing filaments of unequal length from its convex surface; carpospores obovate or oblong produced in longer or shorter chains from the apical segments of the filaments.

About 50 species, all marine, generally distributed, many of the species exceedingly varied in habit and distinguished with difficulty.

KEY TO SPECIES.

Frond terete, slender, light to dark red, branching profuse, fairly regular, lateral, in all planes..1. *G. confervoides* (p. 483).

Frond from flat to slightly flattened or rather terete, coarse, usually purple to dark green, branching sparse, irregular, dichotomous or polychotomous and lateral, more or less in one plane..2. *G. multipartita* (p. 484).

1. **Gracilaria confervoides** (Linnæus) Greville. Pl. XCIX, fig. 1.

Fucus confervoides, Linnæus, 1753, vol. 2, p. 1629.
Gracilaria confervoides, Greville, 1830, p. 123.
Gracilaria confervoides. Harvey, 1853, p. 108.
Gracilaria confervoides, De Toni, 1900, p. 431.
P. B.-A. Nos. 384, 1041.

Fronds elongated, terete, vaguely laterally branched, flagelliform, 0.5 to 3 mm. diameter, 14 cm. to 1 m. long, branches elongated, subundivided, branchlets subsecund, slightly attenuated at both ends, filiform, more or less numerous; tetrasporangia numerous, immersed among the cortical cells of short filiform branchlets; cystocarps prominent, hemispherical, numerous on all sides of branches and elongated branchlets, substance fleshy-cartilaginous, color light to dark red.

Warm and temperate seas.

Very abundant throughout harbor, Beaufort, N. C., attached to shells, etc., April to November, less abundant on Fort Macon and Shackleford jetties, abundant on Bogue Beach, abundant in North River, few specimens on coral reef offshore May, 1907, and July to August, 1915, fruiting throughout season; abundant in sound, Wrightsville Beach, N. C., attached to shells; abundant on muddy bottom of tidal marsh, James Island, Charleston, S. C.; abundant on muddy bottom in sound, Port Royal, S. C.

The species varies considerably in the size of plants, coarseness of fronds, and amount of branching, varying from coarse, slightly branched forms to fine, slender, much-branched ones. The habit may be dense or open, according as the branching is more or less abundant, but in all the typical forms the branching is fairly regular and the branches are long, terete, and flexuous. Although some of the specimens approach *G. dura* (Ag.) J. Ag. in appearance and structure, they do not seem separable from the other specimens, and all have been referred to *G. confervoides*. The specimens from Charleston and

Port Royal formed tangled, irregularly branched, apparently sterile masses, with their bases embedded in mud. Their appearance was quite different from that of the more regular, typical forms growing under favorable conditions at Beaufort.

This species, after being thoroughly washed and bleached, has been successfully used at Beaufort for the making of jellies in a way similar to the use of the "Irish moss," *Chondrus crispus*, of our northern coast.

2. **Gracilaria multipartita** (Clemente) J. Agardh. Pl. XCIX, fig. 2.

Fucus multipartitus, Clemente, 1807, p. 311.
Gracilaria multipartita, J. Agardh, 1842, p. 151.
Gracilaria multipartita, Harvey, 1853, p. 107.
Gracilaria multipartita, Farlow, 1882, p. 164.
Gracilaria multipartita, De Toni, 1900, p. 447.
P. B.-A. No. 885.

Fronds from flat to slightly flattened or rather terete, irregularly dichotomously or polychotomously and laterally branched, 1 to 10 mm. wide, 6 to 36 cm. long, branches short or long, sometimes almost simple; tetrasporangia immersed among the cortical cells of the upper segments or over the greater part of the frond; cystocarps very prominent, scattered over the greater part of the frond; texture coarse, substance cartilaginous, color rose red to purple to olive green to light green.

American and European shores of temperate North Atlantic.

Abundant on Fort Macon and Shackleford jetties, Beaufort, N. C., throughout the year from low water to 1.3 m. below low water, less abundant attached to shells in harbor, abundant on Bogue Beach, fairly abundant in North River; abundant in Core Sound at Lecklys Island and Davis Island, fruiting throughout year; very abundant, Ocracoke, N. C.; abundant in sound, Wrightsville Beach, N. C.; abundant in bay, New Inlet, Southport, N. C.; fairly abundant on jetty exposed to sea, Norris Island, Charleston, S. C., from top of rocks washed by waves to depth of 15 cm.

Var. angustissima Harvey.

Gracilaria multipartita var. *angustissima*, Harvey, 1853, p. 107.
Gracilaria multipartita var. *angustissima*, Farlow, 1882, p. 164.
P. B.-A. Nos. 240, 634.

Fronds rather slender and terete, slightly flattened, especially at the axils, 0.5 to 3 mm. wide, 8 to 22 cm. tall, branching more or less regularly dichotomous, often irregular, usually palmatifid at the tips.

Extremely abundant rooted in mud in mouth of one creek in sound, Port Royal, S. C.

This species is exceedingly various in habit, size, diameter, amount of flattening, and manner and amount of branching, varying from plants up to 4 mm. wide and 12.5 cm. tall, greatly flattened throughout, to plants 1 to 1.5 mm. wide and 36.5 cm. tall, nearly terete over most of thallus. Some of the specimens closely resemble specimens referred to *G. compressa* (Ag.) Grev. and other species, but all so overlap that it is impossible to separate them into more than one species, and all are accordingly referred to *G. multipartita*. The variety is not separable from the species and many of the Beaufort specimens might properly be called var. *angustissima*. The specimens from Port Royal referred to the variety are slender, 1 mm. in diameter, 10 to 13 cm. tall, fairly regularly dichotomous.

Three specimens (two cystocarpic and one antheridial) collected on Bogue Beach, Beaufort, N. C., August, 1908, several fragments found on the beach at different times, and one specimen dredged from the coral reef offshore May, 1907, differ decidedly in appearance from all other specimens of the species from this region being thinner and more delicate and membranaceous when dry and being rosy pink instead of green or purple, as are the other specimens; they have the appearance of species of Halymenia. The structure of the antheridia and the cystocarps, however, certainly refers them to this genus, and the structure of the frond is like that of undoubted specimens of *G. multipartita*.

Specimens of *G. confervoides* and *G. multipartita* have frequently been wrongly determined by collectors and are confused in herbaria. In this region, however, they are fairly distinct, although *G. multipartita* var. *angustissima* approaches some of the coarser forms of *G. confervoides*. They may be distinguished as follows: *G. confervoides* is terete throughout, branching fairly regular, branches usually long and tapering at each end, substance usually less cartilaginous and habit finer than in other species, color some shade of red. *G. multipartita* is flattened in some of its extent, if mostly terete is flattened in axils, in such cases is often palmately divided at flattened apices of branches, branching irregular, substance more cartilaginous and habit coarser than in other species, color from light green to dark green to dark reddish purple.

On our coast *G. confervoides* is the more southern form, being recorded for only one locality north of Long Island Sound. At Beaufort *G. confervoides* occurs mainly in the harbor and has been found only from April to November; *G. multipartita* occurs mainly on Fort Macon and Shackleford jetties and remains throughout the year.

Genus 2. **Hypnea** Lamouroux.

Hypnea, Lamouroux, 1813, p. 131.

Frond filiform, rather terete, virgately or divaricately, more or less richly branched on all sides, often with numerous short, spinelike branchlets; fertile and sterile specimens often very different in appearance; structure cellular, traversed by a more or less evident segmented central axis, inner cortex dense, composed of larger cells within, smaller ones toward the surface, outer cortex thin, composed of small vertical cells arranged in subsingle series; tetrasporangia scattered, embedded in the thickened outer cortex of slightly swollen ultimate branchlets, zonately divided; cystocarps almost spherical, prominent on ultimate branchlets, pericarp fairly thick, sometimes perforated by an apical pore, sometimes opening only by the separation of cells at the apex, attached to the base of the cystocarpic cavity by a network of filaments, gonimoblast arising from the base of the cystocarpic cavity, much branched, attached here and there to the network of sterile filaments and at these points giving off radiating tufts of short filaments whose end cells form short chains of carpospores; antheridia arising on the surface, forming a row of four spermatia from each spermatangium; tetrasporangia, cystocarps, and antheridia borne on different plants.

About 25 species in temperate and tropical seas.

Some of the species are easily distinguished, but some are separated by slight (perhaps doubtful) characters and are very difficult to determine. Determination is made still more difficult by the diversity in different forms of the same species, the cystocarpic plants of different species being said in some cases to resemble each other more than do the cystocarpic and tetrasporic plants of the same species. A revision of the genus is needed, and such a study will probably separate the species along different lines from those used at present.

Hypnea musciformis (Wulfen) Lamouroux. Pl. C; Pl. CI, figs. 1 and 2.

Fucus musciformis, Wulfen, 1789, p. 154; pl. 14, f. 2.
Hypnea musciformis, Lamouroux, 1813, p. 131.
Hypnea musciformis, Harvey, 1853, p. 123.
Hypnea musciformis, Farlow, 1882, p. 156.
Hypnea musciformis, De Toni, 1900, p. 472.
P. B.-A. Nos. 196, 2185.

Fronds filiform, 4 to 50 cm. tall, virgately or divaricately, more or less richly branched, branches long, virgate, and rather sparingly clothed with small subulate branchlets, or short, bearing numerous short branches which are densely covered with minute, spinelike branchlets; apices of the branches often thickened and recurved to form tendrils, either naked or bearing short branches on their convex surfaces; tetrasporangia immersed in the thickened outer cortex, scattered over swollen portions at or near the bases of small subulate ultimate branchlets, zonately divided; cystocarps prominent, usually on small spinelike or subulate ultimate branchlets; cystocarpic and tetrasporic plants sometimes differing in habit; color dark green to light reddish green.

Warm and temperate seas.

Very abundant on Fort Macon jetties and in harbor, Beaufort, N. C.; less abundant on Shackleford jetties, attached to rocks, shells, and Zostera, from low water to 60 or 90 cm. below low water, fruiting, May to October, less abundant and usually sterile, November to April; one plant dredged from coral reef offshore, Beaufort, N. C., August, 1915; abundant in Newport River near Green Rock, in North

River, and in Core Sound at Davis Island and Lennoxville. Very abundant at Ocracoke, N. C., on rocks, shells, and Zostera from low water to 60 cm. below low water. Abundant in sound near inlet, Wrightsville Beach, N. C., on shells 15 to 45 cm. below low water. Few plants about 2 cm. tall in sound near inlet, Pawleys Island, near Georgetown, S. C.

The species varies greatly in appearance. Three types connected by numerous intermediate forms may be distinguished. The first (Pl. C, fig. 1) has an elongated, slender, open habit; the principal branches are not very closely set and are long and virgate; the subsidiary branches are small and slender and are rather scatteringly arranged on the main axis and the principal branches; the ultimate branchlets are numerous on the main axis and the branches, being short, slender, simple, spinelike processes from a narrow base; the apices of the main branches and of some of the subsidiary branches are often incurved and thickened to form tendrils. The second type (Pl. C, fig. 2) has an elongated, more or less slender habit, varying from rather open to rather dense; the principal branches are more or less closely set, more or less elongated, and more or less virgate; the subsidiary branches are more richly branched, and more closely set on the main axis and principal branches than in the first type, and are often larger; the ultimate branchlets more or less densely clothe the main axis and the branches, being shorter or longer, slender or coarser, simple or branched, spinelike processes from a narrow or wider base; the apices of the branches are usually straight and tapering, but are sometimes slightly incurved. The third type (Pl. CI, fig. 1) has a shorter, rigid, dense habit; the principal branches are closely set, short or slightly elongated, and divaricate; the subsidiary branches are short and coarse and are closely set on the main axis and the principal branches; the ultimate branchlets densely clothe the main axis and the principal branches, being short, coarse, branched, staghornlike processes from a broad base; the apices of the branches are straight and taper only at the very ends.

These types are not sharply defined, and different branches of the same frond may show the characters of two or even of all three types. The statements of previous authors that tetrasporic and cystocarpic plants show constant differences in habit do not hold strictly in the present case. Although the majority of plants of the first type are tetrasporic, and, so far as observed, all the plants of the third type are cystocarpic, the first type includes cystocarpic plants also, and the second type includes both tetrasporic and cystocarpic plants. In many cases the tetrasporic and cystocarpic plants are indistinguishable in appearance.

Although some of the Beaufort plants have characters that are given for *H. armata* (Mert.) J. Ag. and *H. divaricata* Grev., others closely resemble the type of *H. musciformis* and other authentic specimens of this species and are so connected with the extreme variants by intermediate forms that it seems impossible to place the specimens in more than one species.

Of the plants observed from July to October, about 80 per cent were tetrasporic and 20 per cent cystocarpic. Only one antheridial plant has been found. In unfavorable situations and in spring (April 21, 1908) all the fruiting plants observed were tetrasporic. The species winters in this region by means of small, matted, slender specimens 1 to 6.5 cm. tall, with short, fine branches (Pl. CI, fig. 2). All such specimens observed, with the exception of some collected April, 1908, were sterile. During the season 1908–9 all specimens observed as late as October 17 had their usual summer size and appearance; those collected November 18 were all in the winter condition as described above; this condition was maintained through the collection of April 15; but on May 14 the species was abundant, with all the plants in the summer condition, many being as tall as 22 cm.

The incurved tips function in a way similar to the tendrils of flowering plants, clasping any small support which they may find, firmly attaching themselves by outgrowths from the surface of contact, and sometimes penetrating within the supporting body. In one case a plant of this species was observed with its tendrils so closely wrapped about a stem of *Leptogorgia virgulata* that they had formed constrictions in the hydroid, the ends of many tendrils were embedded in the Leptogorgia, and some of them bore branches within its body. Since this Leptogorgia does not continue to increase in diameter, it would seem that this was due to the active constriction and penetration of the algal tendrils. The rapidity with which this alga may make active attachments is indicated by the fact that when plants were placed in a jar of sea water with oyster shells they had attached themselves to the shells within 24 hours by the tips of several branches. Similar cases have been observed under natural conditions, some branches bending over and attaching themselves by their tips to the substratum.

Family 2. RHODYMENIACEÆ (Nægeli) Harvey.

Thallus terete, compressed or flat, solid or hollow, or with inflated portions, usually erect, less often horizontally expanded, usually furcately or laterally branched, sometimes variously proliferate or lobate, structure usually cellular; tetrasporangia embedded in the outer cortex, scattered over the surface or confined to nematheciumlike, thickened portions, usually cruciately, more rarely triangularly or zonately divided; antheridia variously formed; carpogonia closely associated with cells which, after fertilization, form the auxiliary cells; cystocarps rather prominent, pericarp thick, usually opening by an apical pore, free or joined to the basal placenta by filamentous strands, gonimoblast more or less compact, divided into several lobes formed simultaneously or successively and arising from a large stalk cell situated in the middle of the placenta, forming carpospores from nearly all the cells.

Nearly 200 species, in nearly all seas, especially in warmer regions, but some in Arctic waters.

KEY TO GENERA

a. Frond solid, erect, flattened .... *b*.
  b. Tetrasporangia situated in definite swollen regions of the thallus .... 1. Rhodymenia (p. 487).
  bb. Tetrasporangia borne in sori scattered over the surface .... 2. Agardhinula (p. 488).
aa. Frond hollow, tubular, terete or slightly flattened .... *c*.
  c. Tetrasporangia cruciately divided; frond hollow in certain regions or throughout .... 3. Chrysymenia (p. 489).
  cc. Tetrasporangia triangularly divided; frond hollow throughout, segmented by constrictions here and there, sometimes with transverse diaphragms .... *d*.
    d. Frond hollow throughout, lacking transverse diaphragms .... 4. Lomentaria (p. 491).
    dd. Frond hollow, but segmented by transverse diaphragm at the constrictions; pericarp with apical pore .... 5. Champia (p. 492).

Genus 1. Rhodymenia Greville.

Rhodymenia, Greville, 1830, pp. XLVIII, 84.

Frond flat, dichotomously or palmately divided, often with proliferations from the margins, usually stalked below; structure cellular, central axis lacking, medullary cells fairly large, oblong, crowded, cortical cells minute, vertically subradiate; tetrasporangia usually confined to definite regions of the thallus, which are sometimes swollen like nemathecia, embedded among the cortical cells, cruciately divided; antheridia forming superficial sori consisting of single layers of minute, hyaline, vertical cells; cystocarps scattered over the frond, hemispherical, opening by an apical pore, fruiting cavity not filled by a filamentous network, gonimoblast inconspicuously lobate, arising from the base of the cavity, the young lobes composed of segmented filaments, the mature ones having many rotund carpospores irregularly grouped in masses, somewhat inclosed by a gelatinous covering.

About 20 species, widely distributed.

Rhodymenia palmetta (Esper) Greville. Pl. CI, figs. 3 and 4.

Fucus palmetta, Esper, 1797, p. 84, pl. 40.
Rhodymenia palmetta, Greville, 1830, p. 88, pl. 12.
Rhodymenia palmetta, De Toni, 1900, p. 514.

Frond flat, decompound-dichotomous, 1 to 20 mm. wide, 2.5 to 18 cm. tall, cuneate at the base, flabellately expanded above, often supported by a cartilaginous stipe 0.3 to 0.7 mm. wide, 1 to 35 mm. long, gradually passing into the widened frond, segments linear, margins smooth, apices acuminate or rotund; tetrasporangia forming single, rounded sori in slightly swollen portions of the frond below the apices of the segments, embedded in the scarcely altered cortical layer; cystocarps rather prominent, hemispherical, sessile, on the margins or surface of the terminal segments; texture membranaceous or slightly fleshy; color light to dark rose.

Temperate North Atlantic; Mediterranean.

Occasional on Bogue Beach, Beaufort, N. C., April to September, sometimes fruiting, occasional on Fort Macon jetties about low water level, May to August since 1906, few plants on coral reef offshore, May, 1907, and August, 1915.

The habit of this species ranges from tall, slender, little-branched forms to short, wide, compact, much-branched ones; the texture varies from thin, membranaceous to rather thick fleshy; the widened frond may arise almost directly from the base or may be borne on a more or less elongated stipe. Sometimes the older portions of the frond are membranaceous, while the younger apices are fleshy.

At Beaufort the plants growing on the jetties were compact, fleshy, and much branched, while many of those from the beach were membranaceous and sparingly branched. Plants were not observed growing in the harbor before 1906. This is the northern known limit of the species on our coast.

Genus 2. **Agardhinula** De Toni.

Agardhinula, De Toni, 1897a, p. 64.

Frond flat, dichotomously branched, structure cellular, the medullary portion composed of several series of large, rounded cells, with smaller cells toward the periphery and in the spaces between the larger ones, the cortical portion composed of 1 to 3 layers of small cells, sometimes arranged in vertical rows; tetrasporangia borne in sori scattered over the surface, immersed in the thicker portions of the cortical layer, cruciately divided; cystocarps prominent, scattered over the frond, hemispherical, opening by an apical pore, gonimoblast attached by a few filaments to the flat base of the fruiting cavity, forming a compact, rounded mass of carpospores, very loosely inclosed by branching filaments running from the wall of the cystocarp.

One species.

The structure of the frond in this genus is between that of Rhodymenia and Chrysymenia, more nearly resembling the latter.

Agardhinula browneæ (J. Agardh) De Toni. Fig. 33; Pl. CII, fig. 1.

Callophyllis browneæ, J. Agardh, 1884, p. 36.
Diplocystis browneæ, J. Agardh, 1896, p. 94.
Agardhinula browneæ, De Toni, 1897a, p. 64.
Agardhinula browneæ, De Toni, 1900, p. 523.

Frond flat, decompound-dichotomous or somewhat palmate, sometimes proliferous from the slightly thickened margin, 10 to 30 cm. or more tall, 1 to 5.5 cm. wide, rather thick, tapering below to a cuneate base, segments spreading above rounded sinuses, lower ones wide, upper ones narrower, linear below, dilated above, apices truncate or oblong-obtuse; tetrasporangia in more or less confluent sori covering most of the surface and separated by sterile areas; cystocarps very prominent, densely scattered over the frond, less abundant toward apices; texture cartilaginous-gelatinous; color light pink.

Florida.

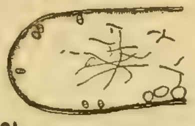
One cystocarpic plant, Bogue Beach, Beaufort, N. C., August, 1903; several plants cystocarpic and tetrasporic, Bogue Beach, September 2, 1903.

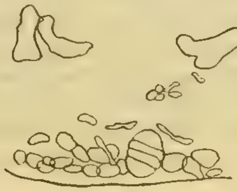
This species has not been previously recorded since its original discovery on the shore of Florida. The Beaufort plants have been carefully compared with a photograph and a fragment of the type; with this they agree in all respects, notably in the structure of the frond and the cystocarp, so that the determination seems reasonably sure. Since this species has been found at Beaufort only on the two days mentioned above, it seems probable that these plants did not grow in this region, but were brought here by the Gulf Stream from some remote southern locality.

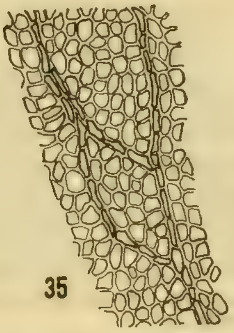
Genus 3. **Chrysymenia** J. Agardh.

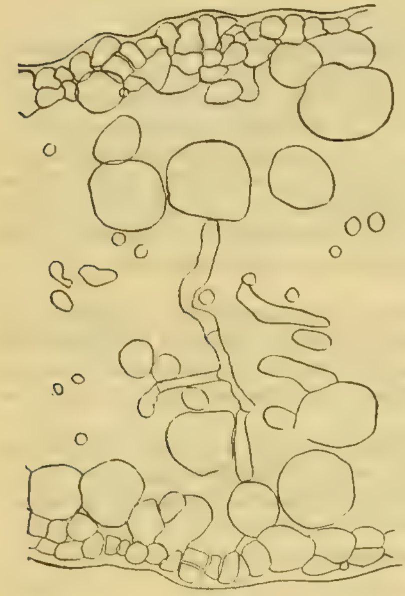
Chrysymenia, J. Agardh, 1842, p. 105.

Frond terete or somewhat flattened, hollow in parts or throughout the entire length, sometimes segmented by constrictions, variously branched, sometimes caulescent and almost solid below with hollow, vesicular, bladderlike lateral branches above; filled with loose jelly; structure cellular, central axis lacking, inner cells large, outer ones smaller, cortical ones minute, scattered filaments sometimes traversing the internal tube; tetrasporangia scattered over the thallus surface, embedded among the cortical cells, cruciately divided; cystocarps scattered over the frond, fairly conspicuous, hemispherical, opening by an apical pore, fruiting cavity with a trace of a filamentous network or entirely lacking this, gonimoblast arising from the base of the cavity, composed of several coalescent lobes, bearing many rotund carpospores irregularly grouped in masses, somewhat inclosed by a gelatinous covering.









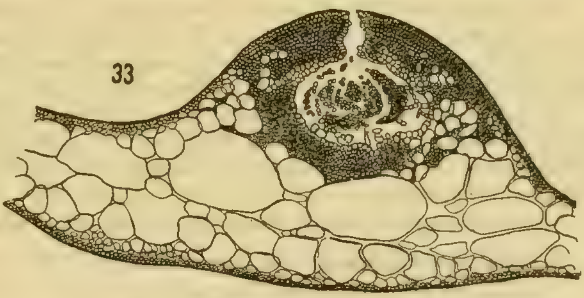


Fig. 31.—*Meristotheca duchassaingii*, showing tetrasporangia and internal structure (diagrammatic) × 30.

Fig. 32.—*Meristotheca duchassaingii*, showing internal structure and tetrasporangium, × 183.

Fig. 33.—*Agardhinula browneæ*, structure of thallus and cystocarp, × 30.

Fig. 34.—*Chrysymenia agardhii*, cross section of thallus, × 183.

Fig. 35.—*Nitophyllum medium* (type), surface view showing veins and cells, × 33.

Fifteen to twenty species in warm seas. Some of the species of this genus resemble in external appearance species of Halymenia, from which they may usually be distinguished by their structure. In the species of Chrysymenia the frond is hollow or nearly so, the wall consisting of one or two loose layers of large cells surrounded by one or two layers of small cortical cells; there are usually no filaments traversing the cavity. In

Halymenia the thallus wall is denser, being composed of smaller, more closely crowded cells, and the cavity is traversed by numerous more or less densely crowded filaments.

KEY TO SPECIES.

Frond flat, leaflike..1. *C. agardhii* (p. 490).
Frond hollow-tubular and gelatinous-membranaceous throughout; laterally decompound .... 2. *C. enteromorpha* (p. 490).
Frond caulescent, solid and rigid below, dichotomously branched, bearing numerous hollow, gelatinous-membranaceous, obovate, bladderlike lateral branches below the apices .... 3. *C. uvaria* (p. 491).

1. **Chrysymenia agardhii** Harvey. Fig. 34; Pl. CII, fig. 2.

Chrysymenia agardhii, Harvey, 1853, p. 189, pl. 30 A.
Chrysymenia agardhii, De Toni, 1900, p. 538.
P. B.-A. No. 746.

Frond flat, leaflike, 5 to 20 cm. long, about 2 to 5 cm. wide, broadly cuneate at the base and tapering gradually into a rather short stipe, dichotomous or subpalmately laciniate, sometimes simple, sometimes irregularly pinnate by lobes from the margins; segments rather broad, approximate above narrow axils, marginal ones somewhat attenuate toward the base, terminal ones attenuate, obtuse; margin wavy, usually eroso-denticulate; thallus rather thick, bearing a more or less conspicuous cavity traversed by branched, segmented filaments, which are fairly numerous in some places, sometimes joining the thallus walls, wall composed of one or two layers of very large cells bordered by 1 to 3 layers of small cortical cells; cystocarps rather prominent, bluntly conical, scattered over the surface of the segments; color bright rose, becoming pale rose or brownish when dry; texture gelatinous-membranaceous.

Florida.

Four sterile plants 7 to 18 cm. long, dredged on coral reef offshore from Beaufort, N. C., August, 1914.

This species resembles *Halymenia floridana* and *H. gelinaria*. From the former it is distinguished by its more gelatinous texture and its thicker frond, with larger cells and fewer internal filaments. From the latter it is distinguished by its less gelatinous texture, its thicker frond with larger, more numerous cells, and the absence of papillæ on the surface.

In none of the specimens has there been observed as abundant filaments or as thick a cortex as is figured by Harvey, and the cortical cells have not been observed in vertically seriate rows. Thick sections, however, especially under low magnification, may give an appearance similar to that shown in Harvey's illustrations.

This is the northern known limit of the species and of the genus.

2. **Chrysymenia enteromorpha** Harvey. Pl. CIII.

Chrysymenia enteromorpha, Harvey, 1853, p. 187.
Chrysymenia enteromorpha, De Toni, 1900, p. 545.
P. B.-A. No. 386.

Frond tubular-hollow, terete or flattened, about 5 to 30 cm. tall, 4 to 8 mm. in diameter, arising from a slightly tapering base, laterally decompound branches elongated, similar to the main axis, constricted at their bases, apices obtuse, often narrowed below the apex and terminated by an obtuse apiculum; main branches flattened or terete, ultimate branches and branchlets terete; thallus wall consisting of one or, more rarely, two loose layers of large cells bounded by a single layer of minute cortical cells; cavity of frond filled with soft jelly; tetrasporangia inconspicuous, scattered over the surface without order among the cortical cells, cruciately divided; cystocarps small, not very prominent, scattered over the branches; texture delicate gelatinous-membranaceous; color light yellowish to rosy pink.

Florida and West Indies.

Two specimens, one tetrasporic, the other cystocarpic, Bogue Beach, Beaufort, N. C., August, 1907, one specimen dredged from coral reef offshore, August, 1914.

The specimens from Bogue Beach (Pl. CIII, fig. 1) and the one from the coral reef (Pl. CIII, fig. 2) differ greatly in appearance, although both seem to come within the range of the species.

The doubt expressed by De Toni (l. c.) concerning the placing of this species in this genus apparently based on the lack of knowledge concerning the method of division of the tetrasporangia, seems removed by the observation of the author that these divide cruciately, as is characteristic for the genus.

This is the northern known limit of the species and of the genus.

3. **Chrysymenia uvaria** (Linnæus) J. Agardh. Pl. CIV, fig. 1.

Fucus ovarius, Linnæus, 1765, Tom. 3, p. 714.
Chrysymenia uvaria, J. Agardh, 1842, p. 106.
Chrysymenia uvaria, Harvey, 1853, p. 191, pl. 20 B.
Chrysymenia uvaria, De Toni, 1900, p. 543.
A. A. B. Ex. No. 150.
P. B.-A. Nos. 289, 1933.

Frond 2.5 to 22 cm. tall, consisting of a solid, terete, rigid, dichotomous, stemlike portion 0.5 to 1 mm. in diameter, naked below, bearing numerous small, hollow, obovate, bladderlike lateral branches on short stalks above; several fronds arising from a common disklike attachment; tetrasporangia and cystocarps borne on the vesicular lateral branches; tetrasporangia immersed in the cortical layer, triangularly divided; cystocarps not abundant in any branch, not very prominent; texture of stemlike portion cartilaginous, of the vesicular lateral branches gelatinous-membranaceous; color rose.

Florida; West Indies; Bermuda; Canary Islands; Mediterranean and adjoining regions; Hawaii.

Occasional on Bogue Beach, Beaufort, N. C., summer and autumn, fairly abundant on coral reef offshore May, 1907, August, 1914, and July to August, 1915.

This is the northern known limit of the species and of the genus on our coast.

Genus 4. **Lomentaria** Lyngbye.

Lomentaria, Lyngbye, 1819, p. 101.
Chylocladia, De Toni, 1900, p. 572.

Frond terete or slightly flattened, hollow-tubular throughout, sometimes segmented by constrictions, branching various, mostly lateral; structure cellular, central axis lacking, thallus wall usually rather thin, composed of three layers, a loose layer of elongated branched filaments bordering the internal tube and sometimes scatteringly traversing this, a single middle layer of large cells, and an outer layer composed of more or less numerous small cortical cells; tetrasporangia borne on slightly dilated branchlets, in cavities formed by the depression of the thallus wall, protruding into the internal cavity, scattered or sometimes joined into groups, triangularly divided; antheridia borne at the ends of short, cellular filaments arising from the cortical cells, forming superficial sori; cystocarps scattered over the frond, rather prominent, globose or subconical, opening by an apical pore, fruiting cavity usually lacking a filamentous network or sometimes with a trace of this; gonimoblast arising from the base of the cavity, composed of several successively formed lobes, bearing numerous oblong or obovate carpospores from the outer segments of branched fruiting filaments, at first arranged radiately, at length conglobate without conspicuous order, usually inclosed by a gelatinous covering, pericarp connected to base of the cystocarp by filamentous strands separating the groups of spores.

About 15 species, in warm and temperate seas.

KEY TO SPECIES.

Frond rather terete, branching irregular, often secund, branches slender, often recurved .... 1. *L. uncinata* (p. 492).
Frond somewhat flattened, branching regular, distichous, branches compact, not recurved .... 2. *L. rosea* (p. 492).

1. **Lomentaria uncinata** Meneghini. Pl. CIV, fig. 2.

Lomentaria uncinata, Meneghini, in Zanardini, 1840, p. 215 (21).
Chylocladia baileyana, Harvey, 1853, p. 185, pl. 20 C.
Lomentaria uncinata, Farlow, 1882, p. 154.
Chylocladia ? uncinata, De Toni, 1900, p. 574.
A. A. B. Ex. No. 75 (*Lomentaria baileyana*).
P. B.-A. Nos. 886, 1399.

Frond rather terete, 0.1 to 1 mm. in diameter, 1 to 12 cm. tall, hollow throughout, not segmented by constrictions, branching usually fairly profuse, irregular, often secund, branches tapering, often recurved, sometimes becoming attached by their apices, branchlets fusiform, constricted at the base, tapering at apex, and irregularly borne; tetrasporangia in slightly thickened branchlets; antheridia usually occurring on separate plants, usually borne at the apices of branches, in enlarged, spherical heads composed of short, radiating, club-shaped, 2 to 4 celled filaments arising from the cortical cells and bearing the antheridia at their apices; cystocarps ovoid, sessile on the branchlets; texture gelatinous-membranaceous; color dull rose, sometimes yellowish or greenish.

New England to Florida and West Indies; Mediterranean.

Fairly abundant along town front and on Fort Macon jetties, Beaufort, N. C., April, 1908, occasional on other algæ and on Ascidian, *Styela plicata*, in harbor, summer and autumn, fairly abundant on sea buoy, September, 1905. One small mass on buoy in sound, Port Royal, S. C., August, 1909.

This species is most easily recognized by its recurved branches, which may bend down and become attached at the apices. Such branches may give off other branches from their convex sides, some of which may in turn bend down and become attached, the continuation of this process giving rise to an appearance like a series of arches. The plants of this species growing in the harbor at Beaufort in April, 1908, were well developed, being 2 to 4 cm. tall; those found during the summer and autumn are minute, scarcely recognizable forms 1 cm. or less in height.

2. **Lomentaria rosea** (Harvey) Thuret. Pl. CIV, fig. 3.

Chylocladia rosea, Harvey, 1853, p. 186.
Lomentaria rosea, Thuret in Le Jolis, 1863, p. 131.
Lomentaria rosea, Farlow, 1882, p. 155.
Chylocladia rosea, De Toni, 1900, p. 575.
A. A. B. Ex. No. 17.
P. B.-A. No. 1241.

Frond somewhat flattened, 1 to 4.5 mm. wide, 2 to 7.5 cm. tall, hollow throughout, not segmented by constrictions, branching usually profuse, branches straight, tapering, bearing numerous distichous, opposite or alternate simple, or pinnate branchlets, which are lanceolate-oblong above a markedly constricted base; tetrasporangia in the branchlets; cystocarps unknown; texture gelatinous-membranaceous; color bright rose.

North Atlantic shores of America and Europe.

One well-developed specimen on coral reef offshore, Beaufort, N. C., May, 1907.

This species is readily distinguished from the preceding one by its flattened frond, with denser habit, the branches not recurved at the apices, the branchlets being numerous, distichous, regularly opposite or alternate, and greatly contracted at the bases. It is distinguished from *Champia parvula*, which it somewhat resembles, by the lack of constrictions and transverse diaphragms segmenting the frond.

This is the southern known limit of the species.

Genus 5. **Champia** Desvaux.

Champia, Desvaux, 1808, p. 245.

Frond terete or slightly flattened, hollow-tubular, but septate by thin, cellular, transverse diaphragms occurring at more or less conspicuously constricted nodes, branching various; structure cellular, central axis lacking, thallus wall thin, composed of more or less of three layers (a loose layer of elongated filaments bordering the internal tube and sometimes scatteringly traversing this, connecting the diaphragms, a middle layer of larger cells, and an outer layer of more or less numerous smaller cortical cells), often composed of a single layer of large cells; tetrasporangia scattered over the surface of branches and branchlets among the cortical cells, triangularly divided; antheridia usually on separate plants, borne singly on the tips of short filaments which arise in branching clusters from the thallus cells; cystocarps scattered over the frond, ovate, opening by a conspicuous apical pore, arising from the base of the cavity, surrounded by a filamentous network, composed of several simultaneously or successively formed lobes, bearing numerous oblong or obovate carpospores from the outer segments of branched fruiting filaments, conglobate without conspicuous order, inclosed by a gelatinous covering.

About 12 species, in warm and temperate seas.

Champia parvula (Agardh) Harvey. Pl. CIV, fig. 4.

Chondria parvula, Agardh, 1824, p. 207.
Champia parvula, Harvey, 1853, p. 76.
Champia parvula, Farlow, 1882, p. 156, pl. 15, f. 2, 5.
Champia parvula, De Toni, 1900, p. 558.
P. B.-A. Nos. 290, 592, 1934.

Frond slightly flattened, 0.5 to 1.5 mm. wide, 2 to 10 cm. high, branching profuse, often intricate with coalescent branches below, branchlets arising alternately, oppositely, or verticillately, patent, apices tapering slightly, obtuse, bases sometimes slightly constricted, segments of the frond barrel shaped, once or twice as long as broad; tetrasporangia scattered over the branches and branchlets; antheridia forming patches indefinite in extent, occurring sometimes as caps at the ends of branches, usually as bands around older portions of the thallus; cystocarps ovate, scattered, sessile on the branches; texture gelatinous-membranaceous; color light to dark pink, sometimes purplish or greenish.

Warm and temperate North Atlantic; Mediterranean.

Fairly abundant throughout harbor, on Fort Macon and Shackleford jetties, and on Bogue Beach, Beaufort, N. C., April, 1908, fairly abundant on coral reef offshore, May, 1907, and July to August, 1915, occasional in harbor, on jetties, and on buoys during summer and autumn. Rather scarce in sound near inlet, Wrightsville Beach, N. C., July, 1909.

This species may be distinguished easily by its hollow-tubular structure septate by transverse diaphragms at more or less evidently constricted nodes.

Family 3. DELESSERIACEÆ (Nægeli) Schmitz.

Thallus flat, very rarely filiform, sometimes perforate or reticulately fenestrate, simple or forked or lobed or proliferous in various ways, structure cellular, sometimes provided with midrib and veins; tetrasporangia triangularly divided, usually occurring in sori embedded in the locally thickened cortex, scattered over the thallus or occurring on special portions, usually regularly arranged and occurring on both sides of the thallus; antheridia, where known, occurring in small, roundish sori scattered over the surface, usually on both sides of the thallus, the antheridia being cut off directly from thallus cells and giving rise, by successive division, to several spermatia; carpogonia closely associated with cells which function as auxiliary cells; cystocarps rather prominent, sessile, scattered over the frond or occurring on special portions, opening by an apical pore, pericarp usually free from the small basal placenta, sometimes joined to this here and there by remnants of the filamentous network, gonimoblast more or less compact, composed of tufts of branched filaments, which arise from a large, basal stalk cell, are developed simultaneously or successively, are loose or compact, sometimes being grouped into lobes, and bear carpospores singly or in short chains or groups from their apices.

Nearly 200 species, in nearly all seas, principally in warmer, especially Australian, regions.

KEY TO GENERA.

Frond usually dichotomously or pinnately branched, midrib inconspicuous or lacking, veins, when present, usually forming a network over the thallus............1. Nitophyllum (p. 494).

Frond usually simple, sometimes irregularly branched, midrib conspicuous below, veins usually not visible to naked eye, arising pinnately from the midrib...........2. Grinnellia (p. 495).

Genus 1. **Nitophyllum** Greville.

Nitophyllum, Greville, 1830, p. 77.

Thallus flat, thin-membranaceous, sessile or borne on a short stalk, simple or dichotomously branched or lobed or divided in various ways, veins present or absent, if present more or less prominent, sometimes elevated, much branched and usually anastomosing, sometimes more prominent, branched, usually anastomosing nerves and occasionally a slight midrib also present; composed of one or a few layers of cells, outer cells large and irregularly angular in surface view, squarish or oblong in section, cells of inner layers sometimes different from the outer ones, veins and nerves composed of several layers of narrow, elongated cells; apical cell evident in the young frond, sometimes persistent for a while, but sooner or later disappearing, the growth of the adult frond being intercalary; tetrasporangia triangularly divided, occurring in sori forming rounded, flattened thickenings prominent on both surfaces of the frond, variously situated in different species; cystocarps scattered over the frond, variously situated, sessile, prominent on both surfaces of the thallus, rounded, slightly flattened, opening by an apical pore, gonimoblast arising from the base of the cavity, composed of radiating, branching, segmented filaments more or less compacted into lobes producing carpospores singly or in short chains from their terminal segments.

About 75 species, in warm and temperate seas.

Nitophyllum medium sp. nov. Fig. 35; Pl. CV; Pl. CXIV, figs. 4 and 5.

Thallus erect, flat, ribbonlike, borne on a (usually short) more or less definite stipe, 5 to 22 cm. tall, 4 to 19 mm. wide, decompound-dichotomously branched, margins usually undulate, often bearing minute proliferations; veins numerous, sometimes conspicuous, sometimes invisible to the naked eye, repeatedly branched, subsingle toward apices, anastomosing frequently throughout most of thallus, coalescent below into stipe; thallus composed of a single layer of cells except at margins and in regions of sori and veins, margins irregularly more or less thickened, sori usually surrounded by more or less extensive regions three cells thick, veins three to five (rarely six) cells thick, usually one (rarely two) cells wide, sometimes bordered by a narrow region of thallus three cells thick; tetrasporangial sori numerous, small, prominent on both surfaces, borne throughout thallus except toward base, forming more or less irregular (often very irregular) parallel or radiating lines, usually between the veins; antheridia and cystocarps unknown; texture thin-membranaceous; color light pink to rose.

Thallo erecto, plano, plus minus definite (plerumque breve) stuposa, 5–22 cm. longo, 4–19 mm. lato, decomposito-dichotome ramoso, marginibus plerumque undulatis, saepe proliferationes minutas ferentibus; venis numerosis, nunc manifestis, nunc oculo nudo invisibilibus, iterum atque iterum ramosis, ad apices subsimplicibus, per maximam partem thalli frequenter anastomosantibus, in inferiore fronde in stipitem coalescentibus; thallo, praeter margines et regiones sororum et venarum, una pagina cellularum composito, marginibus inaequaliter plus minus densis, soris plerumque ab regionibus plus minus latis, 3 cellulis crassis, cinctis, venis 3–5 (rarius 6) cellulis crassis, plerumque 1 (rarius 2) cellulis latis, aliquando ab regione thalli angusta 3 cellulis crassa tactis; soris tetrasporangiorum numerosis, parvis, in superficiebus ambis prominentibus, per thallum, praeter partem inferiorem positis, lineas plus minus irregulares (saepe irregularissimas) parallelas aut radiantes, plerumque inter venas, formantibus; antheridiis et cystocarpiis ignotis; substantia tenue membranacea; colore diluta punicea aut rosea.

Beaufort, N. C.: Occasional on Bogue Beach, February to September, probably throughout the year, often fairly abundant after storms, especially during summer and autumn; several small masses, Fort Macon jetty, July and August, 1906, and one plant September, 1907, 5 to 30 cm. below low tide; few plants on coral reef offshore, 24 to 25.5 m. below surface, May, 1907.

This species seems to belong to the subgenus Cryptoneura J. Ag. In respects other than the arrangement of the sori it closely resembles *N. laceratum* Grev. The structure of these species is so similar that it would seem to indicate a relationship, but the sori are not confined to the margin or marginal proliferations as in *N. laceratum* and other species of the tribe Botryoglossopsis (J. Ag.) De Toni. In many respects *N. medium* resembles species of the tribe Dawsoniæ (Bory) J. Ag. Although the sori are somewhat irregularly arranged and usually are not conspicuously radiating toward the margins, they are not more irregular than in some species of that tribe. The veins are, however, narrower and the margins thicker than in the species under Dawsoniæ which have been available to the author, and the present species does not seem to agree closely with any of the sections under that tribe. If it should be placed under Dawsoniæ, it perhaps agrees best with the section Supradecompositæ J. Ag., although the frond is usually more regularly dichotomous than in species of that section available to the author. Its position in the subgenus must, therefore, be left in doubt pending more extended comparisons.

No specimens have been found by the author except at Beaufort, but several unnamed specimens from points south of this place observed in American herbaria seem to belong to this species. One of these in the herbarium of the New York Botanical Garden is labeled "Delesseria? L. I. G. Pawley's I, July or Aug. 1875." The present known distribution of the species may, therefore, be given as from Beaufort, N. C., to Pawleys Island, near Georgetown, S. C.

The type (Pl. CV, fig. 2) is a tetrasporic plant collected on Bogue Beach, Beaufort, N. C., July 12, 1907. This has a longer stipe than is usually found, but in other respects is a fair average of the species. In other specimens the veins are sometimes more, sometimes less, conspicuous, the sori are sometimes larger and more clustered toward the apices, and sometimes (Pl. CV, fig. 3) more nearly in regular rows, while sometimes the branching is a little more irregular. The type, with several cotypes and other specimens, together with slides used in the study of the species, have been placed in the U. S. National Herbarium.

Genus 2. **Grinnellia** Harvey.

Grinnellia, Harvey, 1853, p. 91.

Frond flat, thin-membranaceous, borne on a short stalk, usually simple, sometimes irregularly branched, traversed by a midrib which is conspicuous below, becoming less conspicuous near the apex, sometimes with lateral nerves arising pinnately from the midrib barely visible to the naked eye; composed of a single layer of cells over most of the frond, at the midrib of several layers of cells, cells irregularly angular in surface view, squarish or oblong in section; apical cell evident in the young frond, soon disappearing, the growth of the adult frond being intercalary; tetrasporangia triangularly divided occurring in sori forming small, rather indefinite thickenings scattered over the frond; antheridia borne at the ends of short filaments arising in clusters from the thallus cells on both sides of the frond; cystocarps scattered over the frond, sessile, hemispherical, rather prominent, pericarp thin, opening by a conspicuous apical pore, joined to the basal placenta by thin, filamentous, sterile strands, gonimoblast composed of rather loose, dichotomously branched filaments which form carpospores from nearly all their cells.

One species, New England to West Indies.

Grinnellia americana (Agardh) Harvey. Pl. CVI, fig. 1.

Delesseria americana, Agardh, 1820, p. 173.
Grinnellia americana, Harvey, 1853, p. 92, pl. 21 B.
Grinnellia americana, Farlow, 1882, p. 161, pl. 13, f. 2–4.
Grinnellia americana, De Toni, 1900, p. 723.
A. A. B. Ex. Nos. 64a, 64b.
P. B.-A. Nos. 593, Fasc. A, No. XXII.

Frond flat, thin-membranaceous, 1 to 11 cm. wide, 6 to 45 cm. long, usually unbranched, supported on a short stalk continuous with the midrib, tapering at each end; tetrasporangial sori appearing as minute dots scattered over the surface, antheridia as small, whitish spots scattered over the frond, cystocarps as evident dots larger and more conspicuous than the tetrasporangial ones; tetrasporangia, antheridia, and cystocarps borne on different plants; color light to dark rosy pink, sometimes purplish.

New England to West Indies.

Fairly abundant throughout harbor and on jetties, Beaufort, N. C., 10 to 30 cm. below low water, December to May, small specimens occasional on Fort Macon jetties during summer and autumn, small specimens on coral reef offshore, May, 1907, and August, 1914; few specimens 1 cm. tall or less, in sound, Pawleys Island near Georgetown, S. C., August, 1909.

Family 4. RHODOMELACEÆ (Reichenbach) Harvey.

Frond terete or flattened, usually richly laterally or dichotomously branched, erect or horizontal, structure usually radial, sometimes dorsiventral, cellular, sometimes cellular-filamentous, usually with a conspicuously polysiphonous axis composed of a segmented central axis surrounded by one or more circles of large pericentral cells of equal length, sometimes covered by one or more layers of small cortical cells, apical cell segmented transversely or obliquely (in one subfamily, Laurenciæ, approaching the tetrahedral type) the thallus bearing more or less numerous, persistent or evanescent, usually much branched, monosiphonous filamentous lateral outgrowths (trichoblasts); tetrasporangia numerous, arising from pericentral cells, embedded in the thallus, covered by special cover cells, scattered over the unaltered smaller branches or in altered branches (stichidia), triangularly divided; antheridia borne on trichoblasts, sometimes apparently on a polysiphonous branch, occurring as small compact bodies of various forms, oval to long cylindrical, terete or flattened, bearing a layer of spermatangia over all or nearly all the surface; carpogonia situated on trichoblasts, sometimes apparently on a polysiphonous branch, closely associated with cells which, after fertilization, produce the auxiliary cells, forming definite procarps sooner or later inclosed by sterile outgrowths from the thallus; cystocarps external, conspicuous, secondarily situated on polysiphonous branches, sessile or borne on short stalks, oval or urceolate, pericarp thick, opening by an apical pore, gonimoblast arising from the basal placenta, consisting of a compressed, more or less compact tuft of richly branched filaments, whose apical cells usually produce single, large, oval, or club-shaped carpospores, but in one subfamily, Dasyeæ, form small cylindrical carpospores in short chains, the spores, in the former case, having the appearance of arising singly on short stalks from the base.

The largest family of the Rhodophyceæ, containing about 600 species, occurring in all seas, especially in the temperate regions of the Southern Hemisphere.

KEY TO GENERA.

a. Growth of thallus sympodial, structure radial, with five pericentral cells, tetrasporangia not completely embedded in the stichidia, branching radial . . . . 7. Dasya (p. 508).
aa. Growth of thallus monopodial . . . . *b.*
  b. Thallus with dorsiventral structure, creeping, bearing elongated, alternate, lateral, creeping branches at regular intervals, and short, erect branches between these, tetrasporangia occurring singly . . . . 6. Herposiphonia (p. 507).
  bb. Thallus usually with radial structure, erect throughout or with conspicuous erect branches from an inconspicuous creeping base . . . . *c.*
    c. Polysiphonous axis not evident, thallus composed of large cells not arranged in circles, apical cell divided somewhat tetrahedrally, tetrasporangia situated without apparent relation to a pericentral cell . . . . 1. Laurencia (p. 497).

cc. Polysiphonous axis plainly evident, thallus composed of one or more circles of large cells around a row of central cells, apical cell transversely or obliquely divided, tetrasporangia produced from pericentral cells..*d.*

d. Thallus with conspicuous erect branches from a creeping base, distichously branched, pericentral cells with secondary transverse divisions.......5. Bostrychia (p. 506).

dd. Thallus erect throughout, radially branched, pericentral cells without secondary transverse divisions..*e.*

e. Trichoblasts persistent, covering portions of the frond in the form of colored, branched, monosiphonous filaments...........................4. Brongniartella (p. 505).

ee. Trichoblasts evanescent, occurring only on the younger portions of the frond........*f.*

f. Thallus with dense parenchymatous structure, polysiphonous arrangement not conspicuous, covered by a dense cortex, pericarp thick, tetrasporangia occurring singly without conspicuous order in spindle-shaped branchlets markedly constricted at their bases..2. Chondria (p. 498).

ff. Thallus with rather loose structure, polysiphonous arrangement conspicuous, naked or covered by a thin cortex, pericarp thin, tetrasporangia usually occurring singly in straight or spiral rows in scarcely altered branchlets. ....3. Polysiphonia (p. 502).

Genus 1. **Laurencia** Lamouroux.

Laurencia, Lamouroux, 1813, p. 130.

Frond erect, terete or flattened, richly radially or distichously branched; structure cellular, dense, cells large within, becoming smaller toward the surface, situated without conspicuous order, central row of cells not evident except toward apices, apical cell surrounded by evanescent trichoblasts, sunk in a depression, somewhat tetrahedrally divided, pericentral cells not formed; tetrasporangia scattered over the ultimate, frequently shortened branchlets among the outer subcortical cells, with no apparent relation to pericentral cells, triangularly divided; antheridia oval to oblong, borne on tufts of branched filaments (trichoblasts) arising from the bases of open, scutellate, apical depressions; procarps borne on trichoblasts within the apical depressions, coming secondarily to lie on the surface as a result of later growth, cystocarps scattered over the smaller branches, prominent, ovate to spherical, pericarp thick, opening by an apical pore, gonimoblast composed of branched filaments radiating from a basal placenta, bearing single pear-shaped carpospores in their terminal segments.

About 50 species, often with ill-defined limits and exceedingly difficult to determine, in warm seas.

Laurencia tuberculosa J. Agardh.

Laurencia tuberculosa, J. Agardh, 1852, p. 760.
Laurencia tuberculosa, Harvey, 1853, p. 75.
Laurencia gemmifera var. *β*, Harvey, 1853, p. 73.
Laurencia tuberculosa, De Toni, 1903, p. 801.
A. A. B. Ex. No. 62.
P. B.-A. Nos. 439, 1937.

Frond subterete or slightly flattened, about 1 to 2 mm. wide, 5 to 20 cm. tall, branching alternate subdistichous, pinnately decompound, branches spreading, bearing numerous short, simple, blunt, wart-like tubercular branchlets distichously arranged below, naked toward the apices; tetrasporangia in the short, tubercular branchlets; texture rather cartilaginous; color crimson to fleshy purple.

Florida and West Indies.

Var. **gemmifera** (Harvey) J. Agardh. Pl. CVI, fig. 2.

Laurencia gemmifera, Harvey, 1853, p. 73, pl. 18 B.
Laurencia tuberculosa var. *gemmifera,* J. Agardh, 1876, p. 657.
Laurencia tuberculosa var. *gemmifera,* De Toni, 1903, p. 802.
P. B.-A. No. 141.

Frond terete, branching profuse, alternate, irregular, decompound, forming more or less intricate tufts, branches spreading, bearing numerous short, simple, blunt, tubercular branchlets on all sides, longer and shorter branches intermingled without order; texture cartilaginous and brittle; color light red or yellowish, sometimes greenish.

Florida and West Indies.

Abundant on Bogue Beach and floating in harbor, Beaufort, N. C., August to October, 1905 (few plants tetrasporic), few small masses unattached on bottom near "Green Rock" in Newport River, August, 1906, occasional on Bogue Beach, September, 1906, one large plant (male) on Shackleford jetty about 30 cm. below low water, August, 1907.

The specimens from this locality do not resemble authentic specimens of *L. tuberculosa*, but closely resemble a specimen from Key West labeled "*L. gemmifera*" by Harvey. In herbaria the variety passes over into the species, but in this region the plants are quite uniform, with little variation, and are always light to dark green. They will not be mistaken for any other species occurring at Beaufort, being easily distinguished by the richly and irregularly branched, intricate tufts of stiff, brittle, cartilaginous, dull green fronds bearing numerous short, blunt, tubercular branchlets on all sides.

This is the northern known limit of the species and of the genus.

Besides the above species, there were collected on Bogue Beach in August, 1906, several battered specimens evidently belonging to another species of Laurencia. These somewhat resemble a battered specimen of *L. pinnatifida* (Gmel.) Lamour., but are indeterminable.

Genus 2. **Chondria** (Agardh) Harvey.

Chondria, Agardh, 1817, p. XVIII.
Chondria, Harvey, 1853, p. 19.
Chondriopsis, Farlow, 1882, p. 165.

Frond erect, terete or somewhat flattened, richly branched, branches arising radially or pinnately, usually alternately, virgate, bearing branchlets which are markedly constricted at their bases; structure cellular, with a single circle of five loose pericentral cells surrounded by several layers of smaller cells within the surface and one or more layers of small cortical cells, growing points prolonged or sunk in slight apical depressions, apical cell transversely divided, trichoblasts somewhat persistent, but finally evanescent; tetrasporangia usually numerous, occurring without conspicuous order among the subcortical cells toward the middle or upper parts of spindle-shaped ultimate branchlets, formed from segments of the pericentral cells, triangularly divided; antheridia irregularly oval, sometimes crumpled plates attached by short stalks to trichoblasts on ultimate branchlets, bordered by one or more rows of sterile cells (fig. 39); cystcarps numerous, sessile on the ultimate branchlets, prominent, ovate, pericarp thick, opening by an apical pore, gonimoblast composed of branched filaments radiating from a basal placenta, bearing single large, elongated, pear-shaped carpospores in their terminal segments; tetrasporangia, antheridia, and cystocarps borne on separate plants

About 25 species, often separated by variable characters and exceedingly difficult to determine, in warm and temperate seas.

KEY TO SPECIES.

a. Apices of branches prolonged .... *b*.
  b. Fronds delicate, slender .... 3. *C. tenuissima* (p. 500).
  bb. Fronds coarse, robust, densely branched .... 1. *C. atropurpurea* (p. 499).
  bbb. Fronds coarse, robust, loosely branched .... 2. *C. littoralis* (p. 499).
aa. Apices of branches forming crateriform depressions .... *c*.
  c. Fronds coarse, rigid, brittle, branching sparse below, often dense above, color dark reddish purple .... 4. *C. dasyphylla* (p. 500).
  cc. Fronds of moderate coarseness, flexuous, branching uniformly profuse, color pinkish straw .... 5. *C. sedifolia* (p. 501).

1. **Chondria atropurpurea** Harvey.

Chondria atropurpurea, Harvey, 1853, p. 22, pl. 18 E.
Chondria atropurpurea, De Toni, 1903, p. 831.

Fronds robust, rather coarse, 5 to 26 cm. tall, 0.7 to 2 mm. in diameter in main stems, rather pyramidal in outline, densely, irregularly, alternately branched, main branches elongated, spreading, sometimes virgate, sparingly beset with secondary branches and branchlets, longer and shorter branches interspersed without order, the ultimate branchlets and usually the secondary branches tapering at each end, having the apices prolonged and being markedly constricted at the base, branchlets arising singly or somewhat fasciculately from superficial depressions, spindle-shaped; tetrasporangia in the ultimate branchlets; cystocarps broad-ovate, sessile on the ultimate branchlets; texture cartilaginous, firm; color usually dark reddish purple, sometimes lighter and yellowish.

South Carolina to Florida; Brazil; Japan.

One specimen on shell between jetties, Fort Macon, Beaufort, N. C., August, 1906?

To this species is referred with considerable doubt one specimen from Beaufort. The species has not been observed elsewhere by the author, but should be included as it certainly occurs within our range, the type being from Charleston, S. C. The habit is similar to that of *C. dasyphylla*, from which it is distinguished by its prolonged apices and sometimes by its lighter color. The Beaufort specimen does not show the constrictions at the bases of the secondary branches, the marked constrictions at the bases of the branchlets, or the origin of the latter from superficial depressions, as is characteristic of the species; but resembles the species in other respects. If this determination is correct, this is the northern known limit of the species.

2. **Chondria littoralis** Harvey. Figs. 36 and 37; Pl. CVII, fig. 1.

Chondria littoralis, Harvey, 1853, p. 22.
Chondria littoralis, De Toni, 1903, p. 832.
P. B.-A. Fasc. D, No. XCVIII.

Frond robust, rather slender, 10 to 35 cm. tall, 0.8 to 2 mm. in diameter in main stems, often pyramidal in outline, irregularly or sometimes somewhat dichotomously loosely much branched, main branches elongated, flexuous, tapering, sometimes almost naked and virgate, sometimes more or less densely beset with secondary branches and branchlets, apices more or less prolonged, branchlets about 3 to 25 mm. long, more or less numerous, sometimes crowded, spindle-shaped, constricted at the bases and more or less prolonged at the apices; tetrasporangia borne below the apices of ultimate branchlets; cystocarps ovate, sessile on the ultimate branchlets; texture fleshy cartilaginous; color light straw red.

Florida; West Indies; Mexico; Bermuda.

Sometimes fairly abundant on Bogue Beach, Beaufort, N. C.

The determination of the specimens referred to this species is made with some doubt, but the plants resemble, in most respects, specimens of this species in the herbaria visited, and seem to agree with the description of the species. Among these Beaufort specimens there is considerable variation, the habit being irregular or fairly regular, the branching being more or less profuse, and the apices being conspicuously prolonged, slightly prolonged, or sunken; the habit is usually open; two specimens from Bogue Beach, August, 1907, and August, 1908, respectively, have the habit of *Gracilaria confervoides*, bearing elongated branches arising regularly, and rather few, inconspicuous branchlets. Only tetrasporic fruits have been observed. Whether this determination is correct or not, the species may be expected within our range. If our plants belong to this species, this constitutes their northern known limit, since the specimens referred to this species by Farlow (1882, p. 167) are now attributed, with considerable doubt, to *C. dasyphylla*.

This species is distinguished from *C. atropurpurea* by its larger size, looser habit, longer branchlets, less acute apices, and lighter color. It is distinguished from *C. tenuissima*, which it resembles in habit, by its usually larger size, considerably coarser fronds, and less regular branching.

3. **Chondria tenuissima** (Goodenough and Woodward) Agardh.

Fucus tenuissimus, Goodenough and Woodward, 1797, p. 215, pl. 19.
Chondria tenuissima, Agardh, 1822, p. 352 (excluding synonyms).
Chondria tenuissima, Harvey, 1853, p. 21, pl. 18 F.
Chondriopsis tenuissima, Farlow, 1882, p. 166.
Chondria tenuissima, De Toni, 1903 p. 834.
P. B.-A. No. 42.

Fronds slender, 6 to 24 cm. tall, about 0.5 to 1.5 mm. in diameter in main stems, pyramidal in outline, irregularly, alternately branched, main branches spreading, bearing more or less numerous secondary branches, and slender, spindle-shaped, spreading branchlets about 4 to 10 mm. long, apices conspicuously prolonged, secondary branches and branchlets tapering at the bases; tetrasporangia borne below the apices of ultimate branchlets; cystocarps ovate, sessile on the ultimate branchlets, sometimes occupying almost the entire branchlet.

Warm and temperate North Atlantic; Mediterranean.

Var. baileyana (Montagne) Farlow, Anderson, and Eaton. Pl. CVII, fig. 3.

Laurencia baileyana, Montagne, 1849, p. 63.
Chondria baileyana, Harvey, 1853, p. 20, pl. 18 A.
Chondriopsis tenuissima var. *baileyana*, Farlow, 1882, p. 166.
Chondria tenuissima var. *baileyana*, Farlow, Anderson, and Eaton, 1889, A. A. B. Ex. No. 187.
Chondria tenuissima var. *baileyana*, De Toni, 1903, p. 836.
A. A. B. Ex. No. 187.
P. B.-A. No. 43.

Frond very slender, 3.5 to 20 cm. tall, about 0.2 to 1 mm. in diameter in main stems; more or less loosely branched, branches elongated, erect, rather simple, bearing very slender, spindle-shaped or club-shaped branchlets, tapering at the bases but obtuse at the apices, apices slightly or not at all prolonged.

New England to North Carolina; Europe.

Fairly abundant in harbor north of laboratory, Beaufort, N. C., abundant on Fort Macon jetties, April, 1908, 10 cm. above to 10 cm. below low water, few very slender specimens on shells and other algæ between jetties, Fort Macon, July, 1909, only tetrasporic fruits observed.

This species is usually distinguished without difficulty by its slender habit and long, slender branchlets, although some specimens bear resemblances to *C. littoralis* and *C. atropurpurea*. The variety is distinguished from the species by its more slender habit and the shape of its branchlets, these tapering at the bases and being blunt, obtuse, and slightly or not at all prolonged at the apices, having the shape of a club rather than that of a spindle. Neither the species nor the variety was observed here in May, 1907. This is the southern known limit of the variety.

4. **Chondria dasyphylla** (Woodward) Agardh. Figs. 38–40; Pl. CVII, figs. 2 and 4.

Fucus dasyphyllus, Woodward 1794, p. 239.
Chrondria dasyphylla, Agardh, 1822, p. 350.
Chondria dasyphylla, Harvey, 1853, p. 20.
Chondriopsis dasyphila, Farlow, 1882, p. 166 (excluding variety).
Chondriopsis littoralis, Farlow, 1882, p. 167. (?)
Chondria dasyphylla, De Toni, 1903, p. 842.
A. A. B. Ex. No. 186.
P. B.-A. No. 142.

Fronds robust, coarse, 7 to 20 cm. tall, about 0.5 to 2 mm. in diameter in main stems, often pyramidal in outline, often sparingly branched below, usually densely branched above, branching alternate, fairly regular, sometimes opposite or fasciculate, main branches elongated, spreading, more or less decompound, tapering gradually toward the apices, secondary branches more or less elongated and tapering, ultimate branchlets usually 2 to 5 mm., sometimes up to 2 cm., long, sometimes borne on the main branches, usually abundant on the secondary branches, arising singly or in clusters, markedly constricted at the bases, usually more or less truncate at the apices, cylindrical, club-shaped to top-shaped, apices more or less markedly sunken, usually truncate, sometimes obtuse and rounded, sometimes almost oblong, often with a short, pointed projection; tetrasporangia borne below the apices of ultimate branchlets; cystocarps round-ovate, sessile, lateral below the apices of ultimate branchlets, which are often pointed at the apices, these points later being pushed to one side by the growth of the cystocarps; texture fleshy-cartilaginous, rigid, brittle; color usually dark, purplish red, sometimes yellowish pink.

Warm and temperate North Atlantic; Mediterranean.

Beaufort, N. C.: Abundant on Fort Macon jetties, 0 to 50 cm. below low water, June to October, fruiting throughout the summer and autumn, an occasional battered specimen found during the winter; abundant in harbor south of laboratory, summers 1903 and 1904; fairly abundant on coral reef offshore, May, 1907, and few slender specimens, August, 1914 and 1915. Ocracoke, N. C.: One faded specimen on jetty, August, 1907.

In this region the species is fairly uniform, usually being distinguished by its coarse, rigid, brittle, dark, purplish red fronds densely branched in the upper portions and by the ultimate branchlets, many of which are extremely short and shaped like a top. Tetrasporic and cystocarpic specimens are abundant throughout the summer and autumn, but antheridial plants are rare. Specimens which seemed to be young plants of this species were observed, in fair abundance, on Fort Macon jetties in April, 1908, but the determination could not be made with certainty, and no plants of the species were observed in May, 1907. The species had almost disappeared on October 17, 1908. Specimens have been collected on Fort Macon jetties twice during the winter, a few small, matted plants, 2 to 4.5 cm. tall, in December, 1908 (Pl. CVII, fig. 2), and one battered fragment in February, 1909. While these plants suggest the probability that the species may winter in this condition, they were not found with sufficient regularity during the winter to establish the point. Plants collected June 12, 1909, were large and well developed. This species has not been observed on Shackleford jetties, nor in the harbor since 1904.

Young stages of this species are frequently observed attached to mature fronds of the same species or to other algæ, especially *Padina vickersiæ*. These appear at first as small, convex disks (fig. 40A), from the middle of which single upright shoots arise, and later give off downward-growing filamentous attaching organs from their basal cells (fig. 40B).

From the bases of mature fronds many short branches grow down and branch profusely, sometimes finally into filamentous branches consisting of single rows of large, thick-walled cells. When these branches reach the substratum they spread out into irregular disks, forming a secure attachment for the frond. The bases of the mature fronds are usually covered by a spongelike animal growth and by small tubes of animals, apparently worms.

5. **Chondria sedifolia** Harvey. Pl. CVIII, figs. 1 and 2.

Chondria sedifolia, Harvey, 1853, p. 19, pl. 18 G.
Chondriopsis dasyphila var. *sedifolia*, Farlow, 1882, p. 166.
Chondria sedifolia, De Toni, 1903, p. 845.
P. B.-A. No. 594.

Fronds robust, of medium coarseness, 2.5 to 27 cm. tall, about 0.4 to 1 mm. in diameter in main stems, uniformly branched throughout, branching profuse, usually alternate, sometimes multifid, main branches more or less elongated, straight or curved, spreading in all directions, ultimate branchlets about 2 to 5 mm. long, sometimes borne on the main branches, usually abundant on the secondary branches, usually arising singly, obovate-oblong or somewhat elliptic, usually markedly contracted at the bases, obtuse or acute, usually truncate, at the apices, apices sunken; tetrasporangia borne below the apices of the ultimate branchlets; cystocarps ovate, opening by a conspicuous apical pore, sessile below the apices of ultimate branchlets, the apices later being pushed to one side by the growth of the cystocarps; texture gelatinous-cartilaginous; color reddish brown to pinkish straw.

New England to Florida and West Indies.

Beaufort, N. C.: Fairly abundant on jetties, and attached to Zostera, shells, etc., between jetties at Fort Macon, 15 to 45 cm. below low water, May to September since 1906, not found in earlier years, fruiting throughout the season; one specimen on Fort Macon jetty, December, 1908; fairly abundant on coral reef offshore, July, 1915; fairly abundant in Core Sound on one jetty at Lecklys Island, July, 1908.

This species is distinguished from *C. dasyphylla* by its more slender form, its habit, and its generally lighter color. The branches are borne fairly uniformly throughout and not in clusters in the upper part of the frond; the ultimate branches are more slender and often shorter than in *C. dasyphylla*, but it lacks the short, top-shaped branchlets frequently found in the latter species, and the apices, so far as has been observed, do not bear short, pointed projections. The species has not been found on Shackleford jetties or in the harbor.

Genus 3. **Polysiphonia** Greville.

Polysiphonia, Greville, 1824a, p. 308.

Frond erect (or creeping at first, later becoming erect), usually terete, sometimes slightly flattened, laterally and radially or dichotomously branched, usually elongated and delicate, slender and flexible, or bristlelike and rigid; structure cellular or filamentous-cellular, consisting of a central row of cells surrounded by a circle of 4 to 24 pericentral cells, this primary structure remaining naked or being clothed in the older parts by a layer of small, cortical cells; sometimes small secondary cells are formed outside of and alternating with the pericentral cells, sometimes the central axis is inclosed by a later-developed layer of rhizoidal filaments; the central cells and inclosing pericentral cells are of the same length, so that the frond has a segmented appearance which is evident throughout or, in the corticated species, only in the younger portions; growth monopodial, apical cell transversely or obliquely segmented, trichoblasts often borne in regular order, somewhat persistent, but finally evanescent, secondary shoots often borne in regular order; tetrasporangia arising from the pericentral cells of ultimate branchlets, usually singly and in spiral rows, sometimes in straight rows, covered by special cover cells, triangularly divided; antheridia lanceolate or long elliptical, attached by short stalks to trichoblasts near the apices; procarps borne on trichoblasts near the apices; cystocarps becoming secondarily attached to branches, borne on short stalks or sessile, conspicuous, oval or urn-shaped, pericarp thin, opening by prominent carpostome, gonimoblast composed of branched filaments radiating from a basal placenta, bearing single, large, elongated, pear-shaped carpospores in their terminal segments; tetrasporangia, antheridia, and cystocarps borne on separate plants; sexual and asexual plants alternating with each other in the life cycle.

About 130 species of varied habit and size, often separated by variable characters, in all seas. The genus is easily recognized, but determinations of the species are usually difficult. This is the central, characteristic genus of the family about which all the others are grouped.

KEY TO SPECIES.

a. Frond with four pericentral cells, no cortex .... *b*.
  b. Branching somewhat dichotomous, segments about 1.5 diameters long below, 2 to 5 diameters in branches .... 1. *P. havanensis* (p. 502)
  bb. Branching pinnate, segments about 1 diameter long throughout, sometimes up to 2.5 diameters .... 2. *P. harveyi* (p. 503).
aa. Frond with more than four pericentral cells, no cortex over most of thallus .... *c*.
  c. Frond with 5 to 8 (usually 6) pericentral cells, segments 1 to 3 diameters long, dichotomous .... 3. *P. denudata* (p. 503).
  cc. Frond with 8 to 20 (usually 16) pericentral cells, segments 1 to 4 diameters long, branching pinnate .... 4. *P. nigrescens* (p. 504).

1. **Polysiphonia havanensis** Montagne. Pl. CVIII, fig. 3.

Polysiphonia havanensis, Montagne, 1837, p. 352.
Polysiphonia havanensis, Harvey, 1853, p. 34.
Polysiphonia havanensis, De Toni, 1903, p. 894.
P. B.-A. No. 1043.

Fronds forming erect tufts, 1 to 8 cm. tall, arising from creeping filaments, somewhat setaceous below, capillary above, soft and flaccid, branching somewhat dichotomous, irregular, decompound, with many lateral branches, branches distant, divided into fine branchlets and more or less densely tufted toward apices, sometimes tufted throughout, secondary branches very slender, branchlets usually elongated, tapering; pericentral cells 4, segments 1.5 diameters long below, 2 to 3 diameters in small branches, 3 to 5 diameters in large branches, less than 1 diameter in branchlets, no cortex; tetrasporangia scattered, usually occurring singly, sometimes in pairs, in swollen portions of branchlets; cystocarps small, ovate on upper branches; color light yellowish red to dark brownish red.

Florida; West Indies.

About 10 specimens, Bogue Beach, Beaufort, N. C., February, 1909.

This species may be distinguished from *P. harveyi*, the only other species with four pericentral cells thus far found at Beaufort, by its finer habit, somewhat dichotomous branching, longer segments, and lighter brownish color. Since, however, other species with four pericentral cells may enter this region, no determination should be made without a careful study of all the characters.

This is the northern known limit of the species. It seems probable that the specimens found here were brought by the Gulf Stream from Florida or the West Indies, since it is not likely that the species could grow in winter at a more northern station.

2. **Polysiphonia harveyi** Bailey. Fig. 41A; Pl. CVIII, fig. 4c.

Polysiphonia harveyi, Bailey, 1848, p. 38.
Polysiphonia harveyi, Harvey, 1853, p. 41, pl. 17 A.
Polysiphonia harveyi, Farlow, 1882, p. 171, pl. 15, f. 3-4.
Polysiphonia harveyi, De Toni, 1903, p. 897.
A. A. B. Ex. No. 133a, b.
P. B.-A. Nos. 888, 1400.

Fronds forming globose, bushy tufts 2 to 15 cm. tall, setaceous, rather rigid, branching abundant, decompound, pinnate, sometimes irregular, usually alternate, branches more or less elongated, spreading, sometimes angularly bent, tapering and sometimes divided into numerous fine branchlets toward the apices, secondary branches sometimes almost as coarse as the primary ones, branchlets arising irregularly, more or less abundant over the entire frond, about 1 to 2 mm. long, spinelike, rigid, spreading, tapering toward the apices, simple or forked, often shed from older plants; pericentral cells four, segments short throughout, about 1 diameter in length, sometimes less, sometimes up to 2.5 diameters, no cortex, but in the older portions of the frond four small secondary cells occur outside of and alternating with the pericentral cells; tetrasporangia forming wartlike swellings in the branchlets; antheridia ellipsoid· cystocarps broad-ovate, toward the apices of small branches; color dark purplish red.

Nova Scotia to North Carolina.

Occasionally fairly abundant on buoys and on algæ thrown on Bogue Beach, Beaufort, N. C., July to October, fruiting. Fairly abundant on buoy in sound, Port Royal, S. C., August, 1909 (?).

This species may be distinguished from *P. havanensis*, the only other species with four pericentral cells thus far found at Beaufort, by its coarser habit, more or less regular pinnate branching, shorter segments, and darker purplish-red color. It is the only identifiable species with four pericentral cells that has been found growing in this region. Specimens apparently belonging to this species were collected at Port Royal, S. C., but unfortunately were lost before they were compared with authentic specimens. It remains doubtful, therefore, whether Beaufort, N. C., or Port Royal, S. C., is the southern known limit of the species. Of the fruiting plants observed about 90 per cent were tetrasporic, 5 per cent male and 5 per cent female.

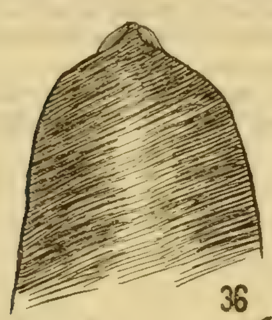
3. **Polysiphonia denudata** (Dillwyn) Kuetzing. Fig. 41B; Pl. CVIII, fig. 4a, b; Pl. CIX, figs. 1 and 2.

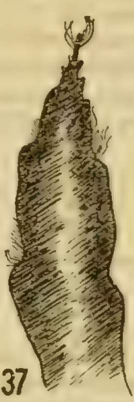
Conferva denudata, Dillwyn, 1809, p. 85, pl. G.
Hutchinsia variegata, Agardh, 1824, p. 153.
Polysiphonia variegata, Zanardini, 1841, p. 60.
Polysiphonia denudata, Kuetzing, 1849a, p. 824.
Polysiphonia variegata, Harvey, 1853, p. 45.
Polysiphonia variegata, Farlow, 1882, p. 173.
Polysiphonia variegata, De Toni, 1903, p. 922.
A. A. B. Ex. No. 135.
P. B.-A. Nos. 245, 639.

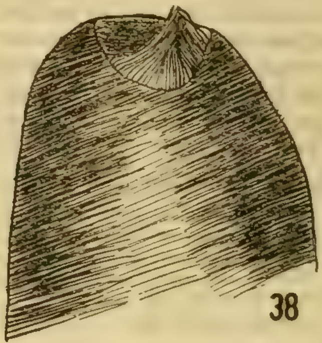
Fronds forming dense, globose tufts, 2 to 25 cm. tall, setaceous and rather rigid below, capillary and flaccid above, branching dichotomous, decompound, abundant, axils spreading below, acute above. branches sometimes elongated and somewhat zigzag, gradually tapering, and divided into numerous fine branchlets toward the apices, branchlets arising laterally, often forming dense fastigiate tufts, especially toward the apices; pericentral cells six to eight, usually six, rarely five, segments 1 diameter long or less below, 2 to 3 diameters above, no cortex; tetrasporangia in somewhat torulose series in the branchlets; antheridia linear-oblong, acute at apices; cystocarps broad-ovate, toward the apices of small branches; color dark brownish or blackish purple.

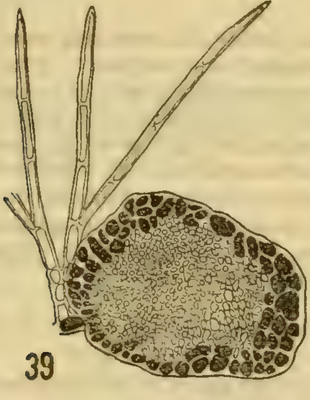
Warm and temperate North Atlantic.

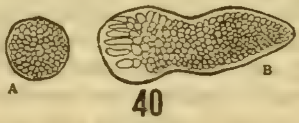
Occasionally abundant on buoys, Beaufort, N. C., July to September, sometimes fruiting. One mass on buoy in Sound, Port Royal, S. C., and very abundant on *Gracilaria multipartita* var. *angustissima* at mouth of one creek, August, 1909.

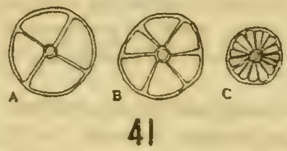


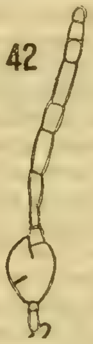












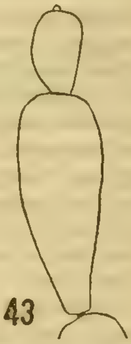


Fig. 36.—*Chondria littoralis*, apex of branch, × 40.
Fig. 37.—*Chondria littoralis* (?), apex of branch, × 40.
Fig. 38.—*Chondria dasyphylla*, apex of branch, × 40.
Fig. 39.—*Chondria dasyphylla*, anthreidium, × 157.
Fig. 40.—*Chondria dasyphylla*, young plants, × 157.

Fig. 41.—*Polysiphonia* spp., cross sections of stems. A. *P. harveyii*. B. *P. denudata*. C. *P. nigrescens*. × 40.

Fig. 42.—*Spermothamnion investiens*, partly divided tetrasporangium producing vegetative filament, × 263.

Fig. 43.—*Griffithsia* sp. × 40.

This is the only determinable species having six pericentral cells observed in this region. The habit, while more or less dense, is characteristic, and the determination is less difficult than in most species of the genus. The plants growing on the buoys are small (2 to 4 cm.), while those from the creek at Port Royal are 6 to 15 cm. tall. According to Harvey, this species is very abundant in the harbor of Charleston, S. C., during January and February.

4. **Polysiphonia nigrescens** (Hudson) Greville. Fig. 41C; Pl. CIX, fig. 3.

Conferva nigrescens, Hudson, 1778, p. 602.
Polysiphonia nigrescens, Greville, in Hooker, 1833, p. 322.
Polysiphonia nigrescens, Harvey, 1853, p. 49.
Polysiphonia nigrescens, Farlow, 1882, p. 174.
Polysiphonia nigrescens, De Toni, 1903, p. 940.

Fronds forming erect tufts 4 to 30 cm. tall, setaceous and rather rigid below, flaccid and much branched above, branching pinnate, alternate, decompound, rather regular, young branches usually pectinate, older ones corymbose above, virgate and beset with short thornlike branchlets below, gradually tapering and more or less divided into fine branchlets toward the apices, branchlets more or less subulate, often compound, arising in clusters over a considerable portion of the frond or especially toward the apices; pericentral cells 8 to 20, usually 16, segments 1 to 4 diameters long, usually 1 to 1.5 diameters, upper and lower ones shorter, no cortex over most of the frond, but sometimes with a thin cortex over the older portions; tetrasporangia forming wartlike swellings in the distorted branchlets; antheridia very long, elliptical, often curved; cystocarps broad-ovate; color dark brownish purple.

Warm and temperate North Atlantic.

Beaufort, N. C.: Fairly abundant on Fort Macon and Shackleford jetties, May, 1907; fairly abundant all over harbor, abundant on Fort Macon jetties, very abundant on Shackleford jetties, and fairly abundant on Bogue Beach, April, 1908, fruiting.

This is an exceedingly variable species, many forms having been described. The habit may be robust with branchlets borne in close pectinate series throughout the frond, or more slender, with the branches more elongated and the branchlets borne in close tufts, especially toward the apices. Usually the branchlets are broken off from the lower parts of the frond, and the remnants of these remain as short, thornlike processes. Often the apices are very finely divided, forming dense, wedge-shaped tufts. Many of these differences seem to depend on the size and age of the plant.

The Beaufort plants have a loose habit, with regular, alternate, pinnate branches, beset below with short thornlike processes, and bearing branchlets in not very dense tufts toward their apices.

This is the only species observed in this region with as many as 16 pericentral cells. In spite of the variations, the determination is not very difficult. It is the only species of the genus so far found at Beaufort during the spring.

Since the identity of *Conferva nigrescens* Hudson is doubtful, it is questionable whether this species should be called *P. nigrescens* or *P. fucoides*, a specific name applied by Hudson to what is undoubtedly the present species. It has, however, seemed proper to keep the current name until it can be clearly shown that this should be changed.

Besides the plants mentioned above, numerous indeterminable small specimens and fragments belonging to this genus have been found at Fort Macon and Shackleford, on buoys, on Bogue Beach, in a tide pool at Fort Macon, and in the harbor, growing on jetties, buoys, shells, other algæ, or animals, or floating free. Some of these resembled *P. harveyi*, some resembled *P. denudata*, while some were too small or too fragmentary to be related to any species. During July and August, 1904, broken fragments of a species with four pericentral cells formed large masses along Bogue Beach and covering the bottom within the inlet at Fort Macon, being the predominant form found there at that time. In December, 1908, tetrasporic specimens 1.5 to 4 cm. tall were collected on Fort Macon jetty, with fine capillary filaments, somewhat dichotomously branched, having four to six pericentral cells. Fruiting specimens about 2 cm. tall, apparently having seven pericentral cells, were found at Pawleys Island near Georgetown, S. C., August, 1909.

Genus 4. **Brongniartella** Bory.

Brongniartella, Bory, in Dictionnaire classique d'histoire naturelle, tome 2, p. 516, 1822.

Frond erect, terete, radially constructed, usually laterally, sometimes dichtomously, branched; structure cellular or filamentous-cellular, with a single circle of five or seven (rarely four) pericentral cells, naked or sooner or later surrounded by a dense rhizoidal cortex, apical growth monopodial, apical cell transversely divided, the entire frond or the younger parts densely covered by spirally arranged, usually more or less dichotomous, colored trichoblasts; lateral branches arising from the basal cells of trichoblasts, forming elongated, vegetative branches or transformed into short, fruiting branches; tetrasporangia numerous, occurring singly in spiral rows in more or less transformed branchlets, triangularly divided; antheridia, procarps, and cystocarps as in Polysiphonia.

About eight species, in warm seas.

The genus is distinguished from Polysiphonia by the persistent trichoblasts and the consequent characteristic habit. It is distinguished from Dasya by its monopodial growth.

Brongniartella mucronata (Harvey) Schmitz. Pl. CIX, fig. 4.

Dasya mucronata, Harvey, 1853, p. 63.
Brongniartella mucronata, Schmitz, 1893a, p. 218.
Brongniartella mucronata, De Toni, 1903, p. 1012.
A. A. B. Ex. No. 2 (*Dasya mucronata*).
P. B.-A. No. 247 (*Dasya mucronata*).

Fronds robust, rather terete, 3 to 20 cm. tall, about 0.5 to 1 mm. in diameter in main stems, one or more arising from a basal, disklike expansion, branching usually lateral and distant, sometimes dichotomous, lower portions of the main stem and larger branches naked, smaller branches and apical portions of larger ones densely covered by monosiphonous, dichotomous, rather rigid, spreading trichoblasts going out on all sides from the cortical layer and mucronate at the apices; pericentral cells five, segments not conspicuous, about 0.5 diameter long in the main stem and larger branches, 1.5 to 2 diameters in smaller branches, covered throughout by a dense cortex; tetrasporangia in somewhat spiral row among the cortical cells of scarcely altered branchlets; antheridia and cystocarps unknown; texture firm, cartilaginous; color of the stem and branches dull, brownish-red, that of the trichoblasts usually brighter, rosy red.

Florida and West Indies.

Occasional on Bogue Beach, Beaufort, N. C., summer and autumn, usually sterile, rarely tetrasporic, few specimens, 3 to 6 cm. tall, dredged on coral reef offshore, May, 1907, and July, 1915.

This species is easily recognized. Neither the species nor the genus is known elsewhere on our coast north of Florida.

Genus 5. **Bostrychia** Montagne.

Bostrychia, Montagne, 1838, p. 39.

Frond usually creeping with erect branches, less often erect, more or less flattened, sometimes apparently terete, branching usually distichous and alternate, sometimes somewhat dichotomous or radial, longer branches bearing two lateral rows of short branches, usually of limited growth, ultimate branchlets simple or branched, often monosiphonous; structure cellular, with a circle of 4 to 11 pericentral cells, the number often varying from base to apex, naked or sooner or later inclosed by one or more layers of cortical cells, the segments sometimes becoming indistinct from the transverse and longitudinal division of the pericentral cells, apical growth monopodial, apices often monosiphonous, often bent or inrolled, apical cell alternately transversely and obliquely divided; tetrasporangia occurring in ultimate, more or less transformed, stichidiumlike branchlets, arising in whorls of 4 to 6 from the pericentral cells, triangularly divided, more or less covered by a layer of small cover cells; antheridia composed of a larger or smaller number of the middle, thickened segments of simple, cylindrical branchlets, the spermatangia occurring in a dense layer over the surface; procarps numerous in single or double rows, embedded in the cortex of slightly thickened branchlets; cystocarps broad-ovate, conspicuous, usually occurring singly, apparently at the apices of branchlets, pericarp fairly thin, opening by a conspicuous terminal carpostome, gonimoblast composed of compressed or more elongated dichotomous-fastigiate filaments, forming single long pear-shaped or club-shaped carpospores from their terminal segments.

About 30 species, mostly in warm regions, usually in brackish water at the mouths of rivers, often extending into fresh water, some species known only in fresh water.

Bostrychia rivularis Harvey.

Bostrychia rivularis, Harvey, 1853, p. 57, pl. 14 D.
Bostrychia rivularis, Farlow, 1882, p. 176.
Bostrychia rivularis, De Toni, 1903, p. 1157.
A. A. B. Ex. No. 54.
P. B.-A. No. 140.

Fronds forming dense tufts, 1 to 4 cm. high, arising from creeping filaments attached to the substratum at intervals by basal disks, capillary, slender, rather rigid, branching decompound, pinnate, alternate, usually distichous, lower branches spreading, almost horizontal, upper ones rather erect, somewhat fastigiate, apices incurved, branchlets usually slightly curved, more or less acute or obtuse at the apices, polysiphonous almost to the apex or terminating in a more or less prolonged monosiphonous portion; pericentral cells 6 to 8 in the principal branches, divided once transversely, thus being half as long as the central cells, segments about 0.5 to nearly 1 diameter long, no cortex; tetrasporangia in stichidiumlike branchlets; cystocarps ovate, terminal on the short, naked, lower branchlets; color dull, brownish purple.

New England to Florida and West Indies.

Very abundant in harbor, Southport, N. C., in brackish water, forming dense covering on wall alongshore from high tide to 30 cm. below high-tide line, fairly abundant on shells alongshore, August, 1909.

This species is easily recognized, having a structure superficially resembling that of Polysiphonia, with regularly, alternately, distichously branched portions arising from creeping filaments, and tetrasporangial branches somewhat resembling the stichidia of Dasya. Its upright branches have a flattened habit, and the main stems have a zigzag appearance, due to their manner of branching. It has not been observed at Beaufort, but may be expected there in brackish water and in similar situations elsewhere.

Genus 6. **Herposiphonia** Nægeli.

Herposiphonia, Nægeli, 1844, p. 238.

Frond creeping, delicate, small, attached at intervals by short, rootlike filaments, rarely entirely erect, terete or flattened, branching lateral, alternate, regular, long and short branches sharply distinct, single, long, creeping branches of unlimited growth arising alternately in two rows from the flanks of the creeping filaments at each fourth segment, single short erect branches of limited growth arising alternately in one or two rows from the dorsal surface of the creeping filaments at all the other segments, creeping filaments dorsiventrally constructed, revolute at the apices, erect filaments dorsiventrally or radially constructed, at first revolute, later becoming straight at the apices and bearing more or less evanescent trichoblasts; structure consisting of a central row of cells surrounded by a circle of numerous (usually 12 to 18) pericentral cells, of the same length, so that the frond has a segmented appearance, no cortex, growth monopodial, apical cell transversely or somewhat obliquely divided; tetrasporangia occurring in more or less broken single rows in the lower or middle portions of erect, short branches, covered by special cover cells, triangularly divided; antheridia lanceolate or long elliptical, attached by short, monosiphonous stalks to trichoblasts toward the apices of erect, short branches; procarps borne on the trichoblasts at the apices of erect short branches; cystocarps as in Polysiphonia.

About 15 species, in warm seas.

Herposiphonia tenella (Agardh) Ambronn. Pl. CX, fig. 1.

Hutchinsia tenella, Agardh, 1828, p. 105.
Polysiphonia tenella, J. Agardh, 1842, p. 123.
Polysiphonia pecten-veneris var. β, Harvey, 1853, p. 46, pl. 16 D.
Herposiphonia tenella, Ambronn, 1880, p. 162.
Herposiphonia tenella, De Toni, 1903, p. 1051.
P. B.-A. Nos. 1044, 1943.

Fronds forming a very fine capillary mat or fringe, composed of creeping filaments with short erect branches, primary filaments decompound, erect, short branches, slender, curved, tapering slightly toward the apices, borne in two rows, coming to lie approximately in one row; pericentral cells 8 to 10, segments 1.5 to 2 diameters long in the primary filaments, about 1 diameter long in the branchlets; tetrasporangia occurring singly in single, straight, unbroken rows of 20 to 30 in erect, short branches; antheridia often borne on every segment for about one-third the length of the branch, beginning about the middle and extending toward the apex; cystocarps usually borne singly on short stalks; texture velvety; color purplish red.

Florida and West Indies; Mediterranean.

Abundant on Fort Macon and Shackleford jetties, Beaufort, N. C., throughout the year, on other algæ, especially *Padina vickersiæ*, and sometimes on the Polyzoan *Bugula turrita*, fruiting August and September, probably throughout the summer and autumn. Fairly abundant on *Dictyota dichotoma*, in sound near inlet, Wrightsville Beach, N. C., July, 1909. Fairly abundant on shells and other algæ, in sound near inlet, Pawleys Island, near Georgetown, S. C., August, 1909.

This species will not be mistaken for any other occurring in this region, being easily recognized by its appearance of a creeping Polysiphonia, forming purplish red, velvety mats or fringes composed of horizontal filaments with upright branches. The species is diœcious. Often all the filaments observed on a single specimen of the host were either sexual (both male and female) or tetrasporic, but sometimes both tetrasporic and sexual plants occurred together.

This is the northern known limit of the species and of the genus.

Genus 7. **Dasya** Agardh.

Dasya, Agardh, 1824, p. XXXIV.

Frond erect, terete, radially constructed, laterally and radially somewhat irregularly branched, long and short branches intermixed; structure cellular or filamentous-cellular, with a circle of five (very rarely four) pericentral cells, naked or inclosed by a more or less dense rhizoidal cortex, apical growth sympodial, the entire frond or the younger parts densely covered by spirally arranged, repeatedly forked, colored trichoblasts; tetrasporangia in whorls (usually of five sporangia) at each segment of special lanceolate branchlets (stichidia) arising as young branches of the trichoblasts and attached to these by monosiphonous stalks, covered by special cover cells when young, uncovered when mature, triangularly divided; antheridia arising as branches of the trichoblasts, lanceolate-conical, ending in a sterile apex, borne on a monosiphonous stalk; procarps numerous near the growing apices of more or less developed lateral branches; cystocarps ovate-globose or urn-shaped, borne laterally on smaller branches, pericarp rather thin, opening by a conspicuous terminal carpostome, gonimoblast composed of dichotomously branched filaments radiating from a basal placenta, forming oval or club-shaped carpospores singly or, rarely, in short chains of two to three spores from their terminal segments.

Thirty to forty species, in warm seas.

Dasya pedicellata Agardh. Pl. CX, fig. 2.

Dasya pedicellata, Agardh, 1824, p. 211.
Dasya elegans, Harvey, 1853, p. 60.
Dasya elegans, Farlow, 1882, p. 177, pl. 15,f. 1.
Dasya elegans, De Toni, 1903, p. 1201.
A. A. B. Ex. No. 51 (*Dasya elegans*).
P. B.-A. No. 545, Fasc. A, No. XXIII (*Dasya elegans*).

Fronds moderately robust, flexuous, terete, 4 to 90 cm. long, about 0.6 to 6 mm. in diameter in main stems, arising singly from a small basal disk, branching lateral, decompound, sparse or profuse, lower portions of the main stem and larger branches naked, smaller branches, and sometimes almost the entire plant, very densely covered by conspicuous, monosiphonous, dichotomous, flaccid trichoblasts going out on all sides from the cortical layer, not tapering toward the apices; pericentral cells five, in the older portions surrounded by one or more layers of smaller secondary cells and always inclosed by a layer of small, cortical cells; tetrasporangia numerous, borne in linear-lanceolate stichidia attenuate at the apices; cystocarps urn-shaped, often excentric, usually single, rarely 2 to 3 together, borne near the apices of short lateral branches; texture soft gelatinous-cartilaginous, flaccid; color light to dark purplish red; tetrasporangia, antheridia, and cystocarps borne on separate plants; sexual and asexual generations alternating regularly in the life cycle.

New England to West Indies; Canary Islands; Mediterranean.

Throughout harbor, and on Fort Macon and Shackleford jetties, Beaufort, N. C., 15 to 45 cm. below low-tide level, very abundant April, 1908, abundant May, 1907, few specimens on coral reef offshore, May, 1907. Collected during the winter and spring 1908–9, as follows: Fort Macon jetty, December, one small fragment; April, large, fruiting; May, small, battered; Bogue Beach, February, sterile; March, fruiting; April, large, fruiting. Few specimens Bogue Beach, July, 1903, and September, 1904; few small specimens attached to stem of *Leptogorgia virgulata* on Fort Macon jetty, August, 1904. One specimen about 1 cm. tall on shell in sound near inlet, Pawleys Island, near Georgetown, S. C., August, 1909.

This species will not be mistaken for any other, being easily recognized by its dense covering of capillary, dichotomous filaments. In this region the species seems to appear in occasional specimens during the winter, reaches its maximal development in April, and almost or entirely disappears by June. Further study is needed to show how it survives from one spring to another, since the occasional specimens observed at other seasons have not been found with sufficient regularity to account for the maintenance of the species.

Family 5. CERAMIACEÆ (Bonnemaison) Nægeli.

Frond terete or flattened, often filamentous, richly laterally or dichotomously branched, usually erect, sometimes partially or almost entirely horizontal, rarely parasitic, structure various, usually composed of naked or more or less corticated filaments; tetrasporangia occurring singly or in groups, in special branches or scattered over the frond, external or sunken in the cortical layer, usually triangularly, sometimes cruciately, divided; antheridia scattered over the thallus in various positions, bearing numerous crowded spermatangia; carpogonia usually closely associated with cells which, after fertilization, produce the auxiliary cells, forming definite procarps of various forms, external, scattered over the thallus or occurring in definite regions, often having two auxiliary cells associated with one carpogonium; cystocarps external or more or less embedded in the cortex, conspicuous, sometimes occurring in pairs, often having two gonimoblasts associated in a single cystocarp, naked or inclosed by special filamentous branchlets forming a more or less lax pericarp, gonimoblast arising from a basal placenta, sometimes compact, usually divided into several more or less conspicuous, usually rounded lobes, consisting of richly branched filaments forming carpospores from nearly every cell.

Nearly 400 species, in all seas, especially in warm regions; two species reported as terrestrial.

KEY TO GENERA.

a. Thallus consisting of monosiphonous filaments entirely or almost entirely without cortex........*b*.
  b. Thallus consisting of erect, laterally branched, filamentous branches arising from horizontal filaments; cystocarps terminal, bearing two gonimoblasts. . 1. Spermothamnion (p. 510).
  bb. Thallus erect, consisting in part of long barrel-shaped or obovoid cells in moniliform filaments; cystocarps terminal, sometimes appearing lateral at the nodes. 2. Griffithsia (p. 511).
  bbb. Thallus erect, main filaments often corticated below with descending rhizoidal filaments; cystocarps lateral, sessile ....3. Callithamnion (p. 511).

aa. Thallus consisting of a monosiphonous central axis partially or entirely surrounded by cortical layers...*c*.
  c. Thallus laterally branched, cortex continuous throughout or lacking only on the finer divisions..4. Spyridia (p. 512).
  cc. Thallus dichotomously branched, forcipate at apices, cortex continuous or present only at the nodes...5. Ceramium (p. 513).

Genus 1. **Spermothamnion** Areschoug.

Spermothamnion, Areschoug, 1847, p. 334.

Thallus composed of erect, naked, monosiphonous filaments arising from creeping filaments attached to the substratum at intervals, erect filaments oppositely or alternately branched; tetrasporangia sessile, occurring singly or in groups on short lateral branchlets, triangularly divided; antheridia ovoid-oblong, sessile on short lateral branchlets, sometimes terminal, composed of minute hyaline cells grouped around a central axis; procarps usually terminal on lateral branchlets, always with two auxiliary cells; cystocarps globose, small, terminal on lateral branchlets, sometimes naked, usually inclosed by short upgrowing, filamentous branchlets, pericarp lacking, containing two gonimoblasts which are small, compressed, and bear numerous single, rounded carpospores radiating in all directions.

About 15 species, in warm and temperate seas.

Spermothamnion investiens (Crouan) Vickers. Pl. XCI, fig. 1.

Callithamnion investiens, Crouan, in Schramm and Mazé, 1865, p. 7.
Callithamnion investiens, Crouan, in Mazé and Schramm, 1870, p. 141.
Spermothamnion investiens, Vickers, 1905, p. 64.

Thallus forming dense woolly tufts, closely enveloping the host plant; primary filaments creeping, attached to the substratum at intervals by unicellular, rhizoidal structures flattened at their ends to form attaching disks, secondary filaments erect, numerous, 1 to 3 mm. tall, 14 to 16 mic. wide, sparingly alternately branched, sometimes simple, branches usually simple, segments 30 to 100 mic. long, usually 55 to 70 mic.; tetrasporangia occurring singly, terminating short (usually one-celled), lateral branchlets, borne oppositely or secundly, ellipsoid or slightly obovate, sometimes almost globose, 30 to 40 mic. wide, 37 to 45 mic. long; antheridia oblong-ovate, borne singly at the apices of more or less prolonged lateral branches or of the main filaments; cystocarps situated like the antheridia; texture velvety; color rose.

West Indies.

Occasionally very abundant on Bogue Beach, Beaufort, N. C., on about half of the specimens of *Zonaria flava* found on the beach throughout the year, fruiting at all seasons, very abundant on about one-third of specimens of *Zonaria flava* dredged off coral reef, May, 1907.

The Beaufort plants are closely similar to Miss Vickers's specimens from Barbados. This species here forms dense, velvety mats covering in almost pure growths the main stems, branches, and larger ribs of the Zonaria. It has been found only on this host except in one instance when a battered specimen of *Brongniartella mucronata* on Bogue Beach had the lower part of its stem densely covered with filaments of this species. It seems very probable that all the plants of *Zonaria flava* found here have come from the coral reef offshore.

It has been noted by Farlow (1882, p. 119) and Lewis (1909, pp. 683, 684) that, in *S. turneri* (Mert.) Aresch, apparent tetraspores may occur on the same individual with procarps, cystocarps, or antheridia. The author has, in the present species, observed cystocarps on the same filaments with what appeared to be undivided tetrasporangia, but has not found cystocarps and mature tetraspores on the same plant. In one instance there was observed a structure (fig. 42) that appeared to be an imperfectly divided tetrasporangium which had continued its growth as a vegetative filament. At Beaufort the masses of Spermothamnion on some specimens of Zonaria seem to be entirely tetrasporic, but on other plants of the host antheridia, cystocarps, and tetraspores occur intermingled.

In spite of its small size, this is the most favorable species found in this region for the study of the structure of the procarp, the process of fertilization, and the development of the cystocarp. Since all the organs are entirely external, these structures appear with diagrammatic clearness, and fruits of all ages are often found in great abundance.

Genus 2. **Griffithsia** Agardh.

Griffitsia, Agardh, 1817, p. XXVIII.

Frond erect, filamentous, composed of simple rows of large, more or less long, cylindrical, barrel-shaped or obovoid cells, naked or possessed of whorls of evanescent, short, branched filaments, branching lateral or dichotomous; tetrasporangia occurring in whorls at the nodes, or on the inner side of short, fascicled branches, usually surrounded by sterile filaments, triangularly divided; antheridia forming compact tufts occupying positions similar to those of the tetrasporangia or densely covering the apices of terminal segments; cystocarps terminal on greatly shortened branches, sometimes appearing lateral at the nodes, usually several occurring together, inclosed by a tuft of sterile filaments, having one or, rarely, two gonimoblasts, gonimoblast usually compact, sometimes divided into several lobes, forming carpospores from nearly every cell.

About 25 species, especially in warm seas.

One small fragment found on Bogue Beach, Beaufort, N. C., August, 1904, seems, from its structure, to belong to this genus, but is insufficient for specific determination; several fragments showing the characteristic structure of the genus (fig. 43) were dredged from the coral reef offshore, August, 1914.

Genus 3. **Callithamnion** Lyngbye.

Callithamnion, Lyngbye, 1819, p. 123.

Frond erect, filamentous, composed of simple rows of cells, naked or, in many species, the main filaments corticated below by rhizoidal, descending filaments, branching abundant, dichotomous or lateral, in the latter case radial throughout, or distichous above, structure monopodial or sympodial, cells multinucleate; tetrasporangia occurring singly or in groups on the upper side of segments of upper branchlets, triangularly divided, sometimes transversely bipartite; antheridia forming small compact tufts of branched filaments of various forms situated on the upper side of upper branchlets; procarps occurring singly or in rows, intercalary on the upper branchlets, usually having two opposite auxiliary cells; cystocarps borne laterally on upper branchlets, sometimes appearing terminal, usually containing two gonimoblasts, sometimes only one, gonimoblasts divided into several successively formed, rounded lobes, producing numerous carpospores, pericarp and encircling branches lacking, but cystocarp inclosed by thin, gelatinous covering.

About 40 species, all marine, very difficult of determination, widely distributed, especially in warm seas.

This genus, which is abundantly represented in some other regions, has few species or individuals at Beaufort and has not been observed by the author elsewhere within our limits. The single species identified at Beaufort (*C. polyspermum*) is, however, reported from Charleston, and representatives will probably be found in other localities along our coast. In determining species, the habit and manner of branching are important characters, and as these distinctions are often difficult to make and some species are variable in these respects, determinations can be made only by careful comparison with authentic specimens.

Callithamnion polyspermum Agardh.

Callithamnion polyspermum, Agardh, 1828, p. 169.
Callithamnion polyspermum, Harvey, 1853, p. 234.
Callithamnion polyspermum, Farlow, 1882, p. 126.
Callithamnion polyspermum, De Toni, 1903, p. 1315

Frond capillary, forming more or less dense tufts 1 to 6 cm. tall, branching profuse, decompound, alternate, radial below, distichously pinnate above, pinnæ naked at the base, pinnulate above the middle; slightly corticated, segments of the main filaments 2 diameters long below, 4 diameters above, uppermost ones shorter; tetrasporangia numerous, secund on the inner side of the pinnules or scattered; cystocarps large, rotund-ovate, occurring singly or up to four or five together; texture flaccid; color bright, purplish rose.

Warm and temperate North Atlantic; Vancouver Island.

Several small tufts on Fort Macon jetty, Beaufort, N. C., June, 1907.

Two small masses of Callithamnion collected on Fort Macon jetty at the same time as the above may also be referred to this species or may be specimens of *C. tetragonum* (Wither.) Ag. Two other specimens from Fort Macon jetty, March, 1909, resemble *C. affine* Harv., but are immature and can not be determined with reasonable certainty. In addition to these, many small masses or fragments insufficient for determination have been found on Bogue Beach at different times.

Genus 4. **Spyridia** Harvey.

Spyridia, Harvey, in Hooker, 1833, p. 336.

Frond erect, usually terete, sometimes somewhat flattened, branching profuse, usually radial, sometimes somewhat distichous, frond beset with numerous more or less fine, hairlike, persistent or somewhat evanescent branchlets composed of single rows of cells, sometimes with layers of cortical cells encircling the nodes or covering the entire branchlet; structure cellular, with a central axis composed of a row of large cells and surrounded, for the most part, by a more or less dense cortex whose cells become smaller toward the surface; tetrasporangia occurring singly or in groups externally at the nodes of hairlike branchlets, triangularly divided; antheridia forming more or less expanded cylindrical patches inclosing portions of the hairlike branchlets; procarps terminal on short branches, bearing two opposite auxiliary cells; cystocarps terminal on short lateral branches, at first having two lobes, later forming three or more irregular lobes, pericarp rather thick, at first closed, later opening irregularly, gonimoblast divided into several lobes composed of dichotomous fastigiate filaments, forming carpospores from their upper segments, these spores appearing in tufts radiating from a placenta that is continuous with the stalk of the cystocarp and is prolonged almost to its apex.

About 17 species in warm and temperate seas.

KEY TO SPECIES.

Ultimate branches not markedly tapering toward the bases, not club-shaped . 1. *S. filamentosa* (p. 512).
Ultimate branches markedly tapering toward the bases, club-shaped.............2. *S. clavata* (p. 513).

1. **Spyridia filamentosa** (Wulfen) Harvey. Pl. CXI, fig. 1

Fucus filamentosus, Wulfen, 1803, p. 64.
Spyridia filamentosa, Harvey, in Hooker, 1833, p. 336.
Spyridia filamentosa, Harvey, 1853, p. 204.
Spyridia filamentosa, Farlow, 1882, p. 140, pl. 10, f. 1, pl. 12, f. 2.
Spyridia filamentosa, De Toni, 1903, p. 1427.
A. A. B. Ex. No. 151 a, b.
P. B.-A. Nos. 393, 1746, 1897.

Fronds moderately robust, terete, 4 to 25 cm. tall, about 1 mm. in diameter below, tapering toward the apices, branching radial, cortex continuous almost to the apices of the branches; branches sometimes recurved, hairlike branchlets more or less abundant, especially over the upper parts of the branches, about 0.5 to 1.5 mm. long, naked, except at the nodes, where they are surrounded by a ring of cortical cells, simple and acuminate at the apices; segments of the branches about equal to the diameter in length or somewhat longer, those of the hair branchlets 2 to 4 diameters long; tetrasporangia borne singly or two to three together at the nodes of the hairlike branchlets; cystocarps two to three lobed, terminal on short, lateral branches; texture flaccid or slightly rigid and brittle; color purplish pink.

Warm and temperate waters generally.

Small fragments in tide pool on "Town Marsh," Beaufort, N. C., September, 1905, two large masses on Bogue Beach, October, 1905, large, battered specimens in tide pool ("Mullet Pond") on Shackleford Banks, August, 1907, few plants dredged from coral reef offshore, August, 1914 and 1915. Abundant on *Zostera marina* in Pamlico Sound, 0 to 30 cm. below low water, August, 1907, Ocracoke, N. C. Few specimens on beach, August, 1909, Georgetown, S. C.

This species is distinguished from the following one by absence of the club-shaped branches and by the numerous fine, hairlike branchlets scattered over the frond and usually abundant on the younger parts of the branches. It is variable in appearance, but good specimens are usually easily recognized. It is not likely to be mistaken for any other species in this region.

2. **Spyridia clavata** Kuetzing.

Spyridia clavata, Kuetzing, 1841, p. 744.
Spyridia clavata, De Toni, 1903, p. 1435.

Fronds slender or moderately robust, rather terete below, flattened above, 8 to 20 cm. long, about 1 to 2 mm. wide, branching distichous, usually alternate, sometimes opposite, larger and smaller branches intermixed, cortex continuous to the apices of the branches; smaller branches tapering toward the bases, larger toward the apices, markedly club shaped, about 2 to 4.5 mm. long, apices acuminate or obtuse; very fine, hairlike branchlets present, but not very conspicuous, naked, except at the nodes, where they are surrounded by a ring of cortical cells, simple and acuminate at the apices; texture gelatinous-cartilaginous, somewhat rigid; color light pink with tinge of green or straw.

North Carolina; West Indies; Senegambia.

Several plants dredged from coral reef offshore, Beaufort, N. C., August, 1914.

This species is distinguished from the preceding by its markedly club-shaped, small branches and by the flattening present in the upper part of the frond. It sometimes resembles, in its gross appearance, *Chondria tenuissima*, but is easily distinguished from this by its evident segments showing through the cortex, resembling in this respect *Ceramium rubrum*.

This is the northern known limit of the species.

Genus 5. **Ceramium** Agardh.

Ceramium, Agardh, 1817, p. XXVI.

Frond erect, terete, slender, of moderate size, branching profuse, regularly dichotomous with forcipate apices, and bearing in addition more or less numerous lateral branches; structure cellular, with a central axis composed of a row of large cells and surrounded at the nodes or throughout by a more or less dense cortex whose cells become smaller toward the surface, sometimes beset with spinelike hairs; tetrasporangia formed from cortical cells at the nodes, naked or inclosed, often becoming prominent and protruding, occurring singly or several together, sometimes forming a single or double circle surrounding the node, triangularly divided; antheridia forming more or less expanded irregular patches over the surface of the cortex on smaller branches; procarps occurring in small numbers on the outer side of the upper dichotomies, bearing two carpogonia; cystocarps lateral, sessile at the nodes, toward the apices of the branches, sometimes appearing almost terminal, surrounded by several short, incurved branchlets, containing one or two gonimoblasts divided into several rounded lobes successively developed and forming numerous angular carpospores inclosed by a hyaline sack, pericarp lacking.

About 65 species, all marine, generally distributed.

The genus is easily recognized by the dichotomous frond consisting of a central row of large cells, with a cortical layer inclosing the nodes or extending over the entire thallus and usually with forcipate tips, but the species are often difficult of determination. Few species have been found in this region, and the two of these that are certainly determinable are usually easily recognized.

KEY TO SPECIES.

a. Cortex covering the entire frond ....2. *C. rubrum* (p. 514).
aa. Cortex confined to band surrounding each node, internodes naked ....*b.*
  b. Tetrasporangia occurring singly at the nodes in secund series or two to four together in a semicircle ....1. *C. tenuissimum* (p. 514).
  bb. Tetrasporangia occurring in single circles surrounding the nodes ....3. *C. strictum* (p. 515).

1. **Ceramium tenuissimum** (Lyngbye) J. Agardh.

Ceramium diaphanum var. *tenuissimum*, Lyngbye, 1819, p. 120, pl. 37, B, f. 4.
Ceramium tenuissimum, J. Agardh, 1851, p. 120.
Ceramium tenuissimum, Harvey, 1853, p. 216.
Ceramium tenuissimum, Farlow, 1882, p. 138.
Ceramium tenuissimum, De Toni, 1903, p. 1450.
P. B.-A. Nos. 497, 798, 1298, 1898.

Frond capillary, of uniform diameter, forming more or less dense tufts usually 2 to 10 cm. high, regularly dichotomously decompound with short, lateral branches scattered here and there, branches erect, spreading, apices forcipate, lower segments 3 to 6 diameters long, nodes slightly swollen, cortex confined to a band surrounding each node and extending for a short distance over the internodes, remainder of internode naked; tetrasporangia occurring singly on the outer side of the upper nodes in secund series or, less often, two to four together forming more or less of a semicircle at the nodes, immersed in the cortical layer, often protruding and prominent; cystocarps lateral near the apices, surrounded by a few short, simple, incurved branches; texture slightly rigid; color purplish or reddish pink.

Temperate waters generally.

Occasional on other algæ, Bogue Beach, Beaufort, N. C., summer and autumn, fruiting.

Here are placed, with some doubt, several small, rather uncharacteristic specimens whose characters, as far as they are shown, seem to agree with this species. These are 0.5 to 3 cm. tall, and bear tetrasporangia usually singly, protruding, inclosed by a cellular covering. Both tetrasporangia and cystocarps are abundant, even on plants only 0.5 cm. tall. The characters of these specimens would, perhaps, agree equally well with those of *C. fastigiatum*, but it may be questioned if these two species are really distinct. With the exception of a single plant, all the specimens of Ceramium which have been found here during the summer and autumn may, perhaps, be referred to this species, but it is possible that some or all of these may be reduced summer forms of *C. strictum*.

2. **Ceramium rubrum** (Hudson) Agardh. Pl. CXI, fig. 2.

Conferva rubra, Hudson, 1762, p. XXVII.
Ceramium rubrum, Agardh, 1817, p. 60.
Ceramium rubrum, Harvey, 1853, p. 213.
Ceramium rubrum, Farlow, 1882, p. 135.
Ceramium rubrum, De Toni, 1903, p. 1476.
P. B.—A. Nos. 345, 646.

Frond robust, tapering toward the apices, 5 to 40 cm. tall, dichotomously decompound with short, sometimes numerous, lateral branches; branches subfastigiate or spreading, apices usually forcipate, nodes often contracted, lower segments 2 to 3 diameters long, cortex covering the entire frond, moderately thick below, thinner above, more or less obscuring the nodes; tetrasporangia immersed among the cortical cells at the nodes, forming one or two circles surrounding the nodes or occurring without order, rather prominent; cystocarps occurring singly or in pairs on the upper branches, surrounded by a few short, incurved branches; texture rather rigid; color dull reddish.

Cold and temperate North Atlantic and Pacific, reported on our coast as far south as Charleston, S. C.

One specimen, Bogue Beach, Beaufort, N. C., April, 1908.

This species will not be mistaken for any other in our region, being easily recognized by the completely corticated fronds. Several varieties have been described.

3. **Ceramium strictum** Harvey. Pl. CXI, fig. 3.

Ceramium strictum, Harvey, 1849a, p. 163 (in part and excluding synonyms, not *Gongroceras strictum* Kuetzing).
Ceramium strictum, Farlow, 1882, p. 136.
Ceramium strictum, De Toni, 1903, p. 1484.
P. B.-A. Nos. 347, 846.

Frond capillary, tapering toward the apices, forming more or less dense tufts, usually 2 to 15 cm. tall, regularly dichotomously decompound with short lateral dichotomous branches scattered here and there; branches fastigiate, apices forcipate, lower segments 4 to 6 diameters long; cortex confined to a narrow band surrounding each node and extending a short distance over the internodes; remainder of internode naked; tetrasporangia occurring in single circles surrounding the nodes, immersed among the cortical cells; cystocarps lateral near the apices of branches, surrounded by a few rather elongated, simple, incurved branches; texture flaccid; color purplish pink.

Temperate North Atlantic; Mediterranean.

Beaufort, N. C.: Few specimens on Bogue Beach, February and March, 1909; very abundant throughout harbor and on Fort Macon and Shackleford jetties, 0 to 30 cm. below low water, April, 1908; fairly abundant throughout harbor and on jetties, May, 1907; on few specimens of *Gracilaria confervoides* from coral reef offshore, May, 1907; one specimen on Fort Macon jetty, July, 1908.

This species varies considerably in the diameter of the frond, the color, and the amount of branching, but good specimens will usually be easily recognized by the narrow bands of cortical cells and the single whorls of tetrasporangia around the nodes. It is the only species which has been observed growing here in the spring. The only species observed in this region with which it is likely to be confused is *C. tenuissimum* (?), from which it is distinguished by its whorls of tetrasporangia and often by its narrower bands of cortical cells. Typical specimens of these species will not be mistaken for each other, but as the tetrasporangia of *C. tenuissimum* are sometimes borne in more or less of a semicircle, and those of *C. strictum* sometimes form incomplete whorls, some specimens will give considerable trouble in their determination. In *C. strictum* the naked internodes are often more conspicuous than in *C. tenuissimum*, being strikingly evident to the naked eye.

This is the southern limit recorded for the species on our coast, but it probably extends farther south in the spring. In this region it seems to appear about February, reach its greatest development in April, and disappear about June, unless some of the small specimens found during the summer are stunted summer forms of this species.

Besides the specimens referred to above, minute, undeveloped plants, insufficient for reference to any species, are found occasionally on other algæ on Fort Macon jetty and on Bogue Beach.

Order 4. **Cryptonemiales.**

Cryptoneminæ, De Toni, 1905, p. 1523.

Carpogenic branches and auxiliary cells occurring separately in the thallus. The fertilized egg cell sends out through the tissue of the thallus more or less long, often branched filaments whose terminal or intercalary cells fuse with single auxiliary cells; thereupon these auxiliary cells develop gonimoblasts toward the surface or interior of the thallus, usually attached to a basal placenta; cystocarps usually immersed.

KEY TO FAMILIES.

Carpogonia and auxiliary cells formed on special secondary filaments, which develop branches forming upright, oval, or flask-shaped structures inclosing the reproductive cells, gonimoblast embedded in the thallus, forming several successive lobes .... 1. GRATELOUPIACEÆ (p. 516).

Carpogonia and auxiliary cells numerous, formed at the base of special flask-shaped conceptacles in the thallus, usually closely associated, gonimoblasts numerous, usually arising from a cell formed by the fusion, after fertilization, of all the auxiliary cells .... 2. CORALLINACEÆ (p. 522).

Family 1. GRATELOUPIACEÆ Schmitz.

Frond usually terete, sometimes angular, flattened or foliaceous, usually laterally, sometimes dichotomously, branched in various ways, nearly always showing a very evident filamentous structure; tetrasporangia scattered over the thallus or confined to special fertile portions, embedded in the cortex or in swollen nemathecia, cruciately divided; carpogonia and auxiliary cells formed on short, special branches of filaments in the inner part of the outer cortex, these branches giving off short lateral branches which inclose the carpogonium or auxiliary cell, forming upright oval or flask-shaped structures, auxiliary cells occurring singly, intercalary in the filamentous branches, branches forming auxiliary cells and, to a less extent, those forming carpogonia, developed in large numbers, intermingled; cystocarps usually small, scattered over the thallus or confined to special portions, usually many occurring near together, embedded in the inner cortex, forming very slight swellings on the surface, usually surrounded by a more or less developed network of filaments, communicating with the exterior by a pore, gonimoblast arising from the base on a more or less large stalk cell, divided into more or less numerous, compact, successively formed lobes, forming numerous carpospores in compact groups.

About 150 species, mostly in warm seas.

KEY TO GENERA.

a. Tetrasporangia formed in nemathecia, cortex parenchymatous, compact, frond foliose, borne on a short stalk..3. Cryptonemia (p. 521).

aa. Tetrasporangia embedded in the outer cortex...*b*.

b. Thallus terete, angular, or flattened, cortex rather thin, small celled, and compact without, large celled and loose within, joining medullary portion by large, scattered, reticulately arranged cells, medullary portion consisting of a loose network of filaments...1. Halymenia (p. 516).

bb. Thallus flattened, cortex rather thick, consisting of compact anticlinal rows of small cells without, looser within, gradually passing over into the medullary portion, medullary portion consisting of a rather compact network of filaments..2. Grateloupia (p. 520).

Genus 1. **Halymenia** Agardh.

Halymenia, Agardh, 1817, p. XIX.

Frond terete, angular, or flattened, dichotomously or laterally branched in various ways, often bearing proliferations from the margins; structure cellular filamentous, medullary portion consisting of a loose network of thin, segmented, branched filaments traversing the inner tube, cortex usually rather thin, small celled and compact without, large celled and lax within, joined to the medullary portion by large, scattered, reticulately arranged cells; tetrasporangia scattered over the frond, embedded in the outer cortex, cruciately divided; antheridia forming colorless patches over the surface of the thallus; cystocarps scattered over the frond, small, inconspicuous, embedded in the inner cortex, forming little or no swelling on the surface, inclosed by a more or less developed network of filaments, communicating with the exterior by a pore, bearing numerous minute carpospores somewhat fasciculately radiating from a central point and tightly inclosed by gelatinous material.

About 25 species in warm seas.

KEY TO SPECIES.

a. Frond terete or slightly flattened, dichotomously branched..................1. *H. agardhii* (p. 517).
aa. Frond with broad, flattened, central axis and main branches and rather terete or slightly flattened secondary branches, laterally branched........................2. *H. floresia* (p. 518).
aaa. Frond flat, expanded, borne on a short stipe, simple or giving off several lobes from near the base, sometimes proliferous from the margins....................................*b.*
  b. Frond gelatinous-fleshy, moderately thick, surface appearing roughly papillate under microscope, many starlike ganglia plainly visible below surface........3. *H. gelinaria* (p. 518).
  bb. Frond firm membranaceous, thin, surface smooth, few starlike ganglia visible below surface, color purplish pink....................................4. *H. floridana* (p. 519).

1. **Halymenia agardhii** De Toni. Pl. CXII, fig. 1.

Isymenia flabellata, J. Agardh, 1899, p. 66.
Halymenia agardhii, De Toni, 1905, p. 1542.
A. A. B. Ex. No. 80 (*Halymenia decipiens*).
P. B.-A. No. 647 (*Halymenia decipiens*).

Frond terete or flattened, 5 to 20 cm. tall, 2 to 10 mm. in diameter, dichotomously decompound, often with a few short dichotomous proliferations, gradually tapering toward the apices, branches rather erect and spreading above, rounded sinuses, habit usually dense, fan-shaped, apices obtuse, inner filaments more or less abundant, intermixed with jelly, irregularly branched, anastomosing, segmented, forming more or less long, cylindrical, or short, somewhat rounded cells; tetrasporangia scattered over the surface among the cortical cells, inconspicuous; cystocarps immersed in the inner cortex, forming no swellings on the surface, appearing as small, inconspicuous dots scattered over the frond; texture rather gelatinous; color yellowish pink to dark, purplish pink.

Florida; West Indies; Bermuda.

Two fruiting plants dredged from coral reef offshore, Beaufort, N. C., August, 1915, occasional on Bogue Beach, summer and autumn, sometimes fruiting.

In typical specimens of this species the dichotomies are frequent, becoming more numerous toward the tips, forming a dense habit with the upper branches crowded, the apices are rounded, and the internal filaments are fairly numerous and usually of uniform diameter. But apparently there is considerable variation among authentic specimens in the size of the plants, the acuteness of the apices, and the amount of spreading of the ultimate branches.

The specimens here referred to this species vary in habit and somewhat in structure. In some the branching is profuse, forming the dense habit given as characteristic of the species, but in others this is distant, forming an open habit. The apices are sometimes rounded, but are more often acuminate, the same specimen sometimes having some branches rounded and others acuminate. The internal filaments may be fairly numerous, but are often sparse. While, therefore, some of the plants do not have all the characters given as typical for the species, authentic specimens themselves vary in these respects. It may be that, in the present case, two species are confused, but it has seemed impossible to separate the specimens into two groups. It has been mentioned that *Dictyota dichotoma*, growing under different conditions, may vary in the acuteness of the apices and may assume habits described for different forms and even different species. No study has yet been made of *H. agarhdii* in this respect, and we do not know enough of the influence of the environment on its form to warrant the separation of species on slight, variable differences in habit.

This species may easily be mistaken for members of other genera reported from Florida, and therefore liable to be cast on our coast. It closely resembles *Halarachnion ligulatum* (Woodw.) Kuetz. The latter species has a more generally open habit, more acute apices and fewer internal filaments than *Halymenia agardhii*, but, as has been mentioned, the latter species may itself vary in these respects. The essential distinction between these species can be made only by the characters of the genera, in that Halarachnion forms its auxiliary cells and cystocarps on the primary filaments, while Halymenia forms these on special secondary branches.

H. agardhii also bears a strong superficial resemblance to *Chrysymenia halymenioides* Harv. Fruiting specimens are easily distinguished, since in the latter species the cystocarps are large and prominent, forming conspicuous excrescences on the surface; sterile specimens may be readily distinguished by the structure, the frond of *C. halymeniodes* forming a delicate tube filled only with jelly, internal filaments being almost or entirely lacking, and the wall composed of only two or three layers of cells.

This is the northern limit of the species and of the genus.

2. **Halymenia floresia** (Clemente) Agardh. Pl. CXII, fig. 2.

Fucus floresius, Clemente, 1807, p. 312.
Halymenia floresia, Agardh, 1822, p. 209.
Halymenia floresia, Harvey, 1853, p. 193.
Halymenia floresia, De Toni, 1905, p. 1545.
P. B.-A. No. 298.

Frond flattened, 6 to 30 cm. tall, arising from a basal disk, supported on a stipe tapering into the frond, pinnately decompound, main axis flattened, 1 to 6 cm. wide, pinnæ flattened, pinnules somewhat flattened or rather terete, both long, linear, acuminate, spreading, margins of pinnæ and pinnules entire or beset with numerous teeth or cilia, inner filaments rather sparse and lax, intermixed with jelly, cortex consisting of one or two layers of cells; tetrasporangia occurring among the cortical cells, inconspicuous; cystocarps suspended within the cortex, inconspicuous, forming no swellings on the surface, appearing as minute dots scattered over the frond; texture gelatinous, delicate; color pinkish straw to bright rosy pink.

Warm North Atlantic; Mediterranean; Red Sea.

One fragment, Bogue Beach, Beaufort, N. C., September, 1904.

The battered fragment found at Beaufort is 12 cm. long, but does not include either the base or the apex. It resembles specimens of the species from other regions, except that it is less frequently branched. This species will not be mistaken for any other within our range.

This is the northern limit of the species and of the genus.

3. **Halymenia gelinaria** Collins and Howe. Fig. 44; Pl. CXII, figs. 3 and 4a.

Halymenia gelinaria, Collins and Howe, 1916, p. 173.
P. B.-A. Nos. 749 (*Halymenia floridana*), 750 (*Halymenia floridana* forma *dentata*), 2050.

Frond flat, about 5 to 60 cm. tall, 3 to 60 cm. wide, borne on a short, narrow, filiform, conspicuous stipe a few mm. long, suborbicular, oblong, ovate, or cuneate-obovate, subentire or rather sparingly parted, lobed, or proliferous, the margins entire or very irregularly cut in various ways; medulla traversed by few or many irregularly branched, conspicuously segmented filaments of different sizes, frequently anastomosing and occasionally forming structures resembling stellate ganglia, cortex one to four cells thick, outermost cells more or less vertically elongate, cuticle frequently dissolved, so that the surface appears papillate; tetrasporangia scattered among the superficial cells; cystocarps numerous, scattered, minute, often slightly protuberant on one surface; texture rather gelatinous; color light purplish pink to dark, purplish red, often with a tinge of greenish yellow.

Florida.

Occasional on Bogue Beach, Beaufort, N. C., summer and autumn, few small plants dredged from coral reef offshore, May, 1907, and July, 1915.

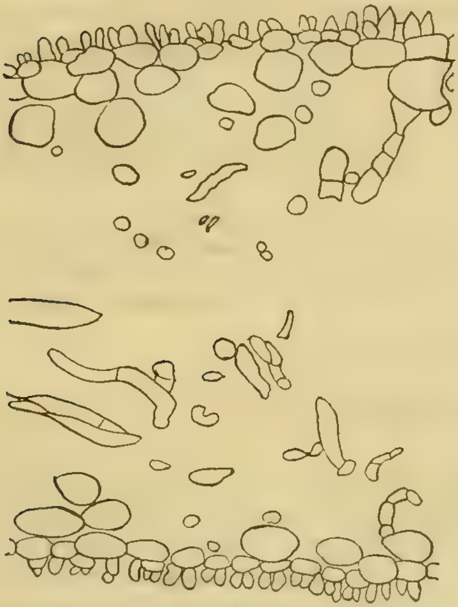
This species, placed in Herb. Agardh under *Halymenia floridana* and included in that species by previous authors, has been separated by Collins and Howe (1916), since it differs decidedly from the form that is generally recognized as the type of that species. It has a rather thick, gelatinous texture, the structure is decidely loose, the cortex consisting of usually one, sometimes two or more, layers of large, loose cells, from which project small, vertical, papillate cells, often not bounded by a definite cuticle; the medullary portion is usually not densely filled with jelly and is traversed by very scattered, irregularly branched, conspicuously segmented filaments of different sizes; anastomoses are often abundant and conspicuous toward the surface; in surface view the surface appears papillate; a subepidermal view seen from the surface shows numerous filaments of various sizes radiating from common centers and anastomosing, but forming a homogeneous part of the structure, heteromorphous "stellate ganglia" being rare; the color is light, purplish pink, to dark, purplish red, usually with a decided tint of greenish yellow.

This species is distinguished from *Halymenia floridana* by its thicker, more gelatinous texture, its looser structure, its papillate surface seen in surface view, its scarcity of heteromorphous "stellate ganglia" in subepidermal view, and its less rosy color, sometimes with a greenish or yellowish tinge. Its cystocarps also appear to the naked eye larger and less dense than in *H. floridana*. The two species may usually be distinguished with certainty, but one specimen (No. 22), having the structure of *Halymenia gelinaria* and accordingly placed in that species, has the color and texture of *Halymenia floridana*.

It is distinguished from *Chrysymenia agardhii*, which it resembles, by its more gelatinous texture, its slightly thinner frond, with smaller, less numerous cells, and by its conspicuously papillate surface.

The structure of the present species closely resembles that of the single specimen of *Halymenia latifolia* that has been available to the author.

This is the northern known limit of the species and of the genus.



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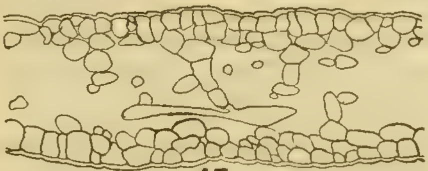

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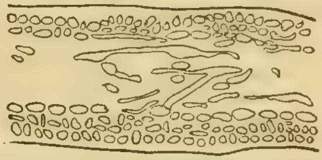

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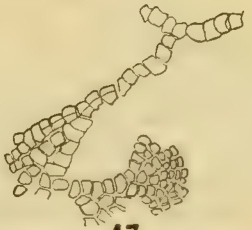

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FIG. 44.—*Halymenia gelinaria*, cross section of thallus (microtome section from preserved material), × 240.

FIG. 45.—*Halymenia floridana*, cross section of thallus (microtome section from dried material), × 240.

FIG. 46.—*Halymenia floridana*, cross section of thallus (hand section from dried material), × 240.

FIG. 47.—*Melobesia farinosa* f. *callithamnioides*, portion of thallus as seen in surface view, × 44.

4. **Halymenia floridana** J. Agardh. Figs. 45 and 46; Pl. CXII, fig. 4b.

Halymenia ligulata, Harvey, 1853, p. 192 (not *H. ligulata* of other authors).
Halymenia floridana, J. Agardh, 1894, p. 59.
Halarachnion ? floridanum De Toni, 1905, p. 1655.
(Not P. B.-A. Nos. 749, 750.)

Frond flat, 5 to 20 cm. tall, 4 to 10 cm. wide, borne on a short, narrow, filiform, conspicuous stipe a few mm. long, at first ovate, entire, later forming numerous ovate lobes cuneate at the bases, tapering toward the obtuse apices, finally laciniate, somewhat palmatifid; medulla traversed by many irregularly branched filaments of irregular sizes, segmented occasionally, but not conspicuously, frequently anastomosing and forming numerous conspicuous stellate ganglia, cortex one to four cells thick, the cells usually of fairly uniform diameter, cuticle persistent and conspicuous, surface smooth; cystocarps occurring singly, appearing as minute dots scattered over the thallus, forming slight swellings on both surfaces; texture thin, membranaceous; color dark rose or purplish pink.

Florida; Bermuda.

Occasional on Bogue Beach, Beaufort, N. C., summer and autumn, sometimes fruiting.

Two distinct forms, a thin, membranaceous one and a thicker, more gelatinous one, have previously been included under this species. Although both these forms seem to be represented under the name "*Halymenia floridana*" in Herb. Agardh[a] the concensus of opinion seems to be that the thin form should be considered as the type, and the thick one has accordingly been separated by Collins and Howe (1916) under the name *Halymenia gelinaria*.

The present species (figs. 45 and 46) has a rather thin, membranaceous texture; the structure is fairly dense, the cortex consisting of one or usually two layers of medium-sized cells apparently formed from the ends of filaments, bounded by a definite cuticle; the medullary portion is densely filled with jelly and is traversed by rather scattered, irregularly branched filaments, segmented occasionally, but not conspicuously, the majority of these being small but mixed with occasional larger filaments, both kinds being irregular in size, anastomoses appear infrequent and inconspicuous in section; in surface view the surface appears composed of small, roundish-angular cells situated close together; a subepidermal view seen from the surface shows conspicuous anastomoses of filaments and numerous heteromorphous "stellate ganglia" apparently formed from the enlarged ends of the larger filaments, from which radiate filaments running parallel with the surface and frequently fusing with similar filaments from other similar ganglia; the color is rather dark, rose or purplish pink.

This species is distinguished from *Halymenia gelinaria* by its thinner, more membranaceous texture, its denser structure, its small cells seen in surface view, its heteromorphous "stellate ganglia" seen in subepidermal view, and its more rosy color. Its cystocarps also appear to the naked eye smaller and denser than in *H. gelinaria*.

From *Chrysymenia agardhii*, which it somewhat resembles, it is distinguished by its more membranaceous texture and its thinner, denser frond, with smaller cells and more numerous internal filaments. It is distinguished from *Callymenia reniformis* (Turn.) J. Ag., with which it has often been confused, by its thinner, more membranaceous, less gelatinous frond, with denser, more regular structure.

This is the northern known limit of the species and of the genus.

Genus 2. **Grateloupia** Agardh.

Grateloupia, Agardh, 1822, p. 221.

Frond flattened, dichotomously or laterally branched in the plane of the flattening, primary frond sometimes simple or irregularly divided, often irregularly proliferous from the margins and sometimes from the flat surfaces; structure filamentous, inner (medullary) layer composed of thin, segmented, reticulately anastomosing filaments, sometimes rather lax, inner cortex moderately thick, lax within, gradually passing over into the medullary portion, outer cortex rather thick, composed of vertical, moniliform filaments; tetrasporangia scattered over the frond, embedded in the outer cortex, cruciately divided; antheridia arising from the outer cortical cells, forming patches over the surface of the frond; cystocarps scattered over the frond or forming irregular groups, small, inconspicuous, entirely sunken within cavities in the cortical layer, communicating with the exterior by an opening formed among the cortical filaments, bearing numerous carpospores in irregular groups radiating from a central point.

About 35 species, mostly in warm seas.

KEY TO SPECIES.

Fronds decompound-pinnate, narrow linear, 0.5 to 2.5 mm. wide................1. *G. filicina* (p. 521).

Fronds rather simple or irregularly divided, finally pinnate from the margins, main axis 0.5 to 4 cm. wide..2. *G. gibbesii* (p. 521).

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[a] The author is indebted to Dr. Marshall A. Howe for information regarding specimens placed under this species in Herb. Agardh.

1. **Grateloupia filicina** (Wulfen) Agardh. Pl. CXIII, fig. 1.

Fucus filicinus, Wulfen, 1789, p. 157, pl. 15, f. 2.
Grateloupia filicina, Agardh, 1822, p. 223.
Grateloupia filicina, Harvey, 1853, p. 200.
Grateloupia filicina, De Toni, 1905, p. 1563.
P. B.-A. Nos. 394, 1449.

Frond flattened, 4 to 45 cm. tall, 0.5 to 2.5 mm. wide, branching decompound-pinnate, sometimes irregular, sometimes bearing proliferations from the flat surfaces, main axes and pinnæ tapering toward the base and apices, linear; pinnæ about 0.3 to 2 mm. wide, lower ones usually longer and pinnulate, upper ones shorter and rather simple; tetrasporangia immersed in the pinnules, inconspicuous, sometimes clustered; cystocarps immersed in the pinnæ, numerous, clustered, inconspicuous; texture tough-membranaceous; color straw pink to reddish or greenish purple.

Warm and temperate waters generally.

One group on Fort Macon jetty, Beaufort, N. C., August, 1906, and July, 1908, 10 to 20 cm. below low water, some tetrasporic.

This species varies considerably in habit, ranging from one main axis with regularly distichous branches from the margins to many axes about equally prominent giving off branches about equal to the main axes; the branching is frequent or infrequent and sometimes is very irregular, with numerous small branches; the main axes are more or less flattened, sometimes being almost terete. In spite of its variability, it is not apt to be mistaken for any other species occurring within our range.

This is the northern known limit of the species and of the genus on our coast.

2. **Grateloupia gibbesii** Harvey. Pl. CXIII, fig. 2.

Grateloupia gibbesii, Harvey, 1853, p. 199, pl. 26.
Grateloupia gibbesii, De Toni, 1905, p. 1566.

Frond flattened, 6 to 60 cm. tall, 0.5 to 4 cm. wide, rather simple or irregularly divided, finally pinnate from the margins, sometimes bearing numerous proliferations from the flat surfaces, main axis and pinnæ tapering toward each end, pinnæ more or less elongated, narrow, linear-lanceolate, often bearing numerous small, narrow pinnules; cystocarps minute, densely scattered through the lobes, embedded in the cortical layer; texture fleshy-membranaceous; color blackish purple, changing to greenish purple.

Abundant on jetty directly exposed to sea, Charleston, S. C., from tops of rocks washed by waves to 15 cm. below low water, Morris Island, July, 1909.

This species is extremely various in habit, the fronds being simple or much divided in irregular ways; the margins and surfaces may be smooth or densely covered with proliferations. In spite of its variation, the species is easily recognized. It is not known beyond Charleston and vicinity.

Genus 3. **Cryptonemia** J. Agardh.

Cryptonemia, J. Agardh, 1842, p. 100.

Frond flat, stipitate, usually provided with a midrib often becoming less conspicuous toward the apices, simple or dichotomous or proliferous from the midrib or margin; structure fairly dense, medullary portion consisting of elongated, segmented, branched, densely interwoven filaments, cortex dense, composed of one or a few layers of large, rounded cells within, small cells without, disposed without definite order; tetrasporangia embedded among the cortical cells, occurring in locally thickened nemathecia borne on special, smaller, usually terminal shoots; cystocarps small, inconspicuous, usually borne on smaller, terminal portions of the thallus, either on special segments or scattered over the surface, communicating with the exterior by a pore, bearing numerous minute carpospores without regular order in a rounded mass suspended from the medullary filaments.

About 10 species, in warm seas.

Cryptonemia crenulata J. Agardh. Pl. CXIII, fig. 3.

Cryptonemia crenulata, J. Agardh, 1847, p. 11.
Cryptonemia crenulata, Harvey, 1853, p. 184.
Acrodiscus ? crenulatus, De Toni, 1905, p. 1599.
A. A. B. Ex. No. 23.
P. B.-A. Nos. 549, 2100.

Frond flattened, ruffled, 2 to 14 cm. tall, 0.5 to 5 cm. wide, supported on a short stipe, which soon passes over into the expanded portion of the thallus, branching dichotomous or almost palmatifid, often with similar expanded, dichotomous proliferations from the margins, margin sometimes entire, usually eroso-denticulate and slightly curled, segments linear or wedge-shaped, rounded, obtuse, or truncate at the apices; tetrasporangia occurring in rounded sori near the margins of the segments; cystocarps appearing as minute dots, scarcely visible to the naked eye, clustered here and there on the surface of the frond; texture membranaceous, rigid; color rosy purple, sometimes slightly greenish.

North Carolina to Brazil.

Occasional on Bogue Beach, Beaufort, N. C., August to October, sometimes bearing cystocarps.

This species was removed from the present genus by De Toni and doubtfully placed under Acrodiscus Zanard. with the note that, according to the suggestion of Schmitz, the latter genus should be united with Polyopes J. Ag. The structure of the cortex of this species is, however, parenchymatous, agreeing with that of *Cryptonemia lomation* (Bertol.) J. Ag., the type of the genus, and is not composed of anticlinal rows of cells, as in Acrodiscus and Polyopes. The species is accordingly retained under Cryptonemia.

This species is easily recognized by the crisp, ruffled frond, which is so rigid that it can be made to lie flat only by considerable pressure. Dried specimens, when moistened, show this character almost as clearly as do living plants.

This is the northern known limit of the species and of the genus.

Family 2. CORALLINACEÆ (Gray) Harvey.

Frond extremely various in form, filamentous, foliaceous, crustaceous, flattened, terete or irregular, simple or dichotomously, laterally or irregularly branched in various ways, sometimes endophytic, nearly always more or less strongly incrusted with lime, structure cellular-filamentous, nearly always compact; tetrasporangia (or sometimes disporangia) occurring in more or less well-defined sori embedded in the thallus, sometimes in definite, flask-shaped conceptacles scattered over the frond or borne in special, swollen portions, often mingled with sterile paraphyses, usually zonately divided, sometimes forming only two spores, communicating with the exterior by one or more pores; antheridia borne in flask-shaped conceptacles formed in the thallus and communicating with the exterior by a pore, scattered over the frond or borne in special swollen portions, forming spermatangia singly on long stalks or in chains, mingled with paraphyses; carpogonia and auxiliary cells numerous, usually borne together on upright, branched filaments arising from the base of flask-shaped conceptacles formed in the thallus and communicating with the exterior by a pore, scattered over the frond or borne in special swollen portions, gonimoblasts numerous, usually arising as single cells from the periphery of a large discoid cell in the base of the conceptacle, formed by the fusion, after fertilization, of all the auxiliary cells, cutting off chains of carpospores in basipetal succession, the numerous carpospores and parphyses finally filling the conceptacle.

Nearly 400 species, widely distributed, mostly in warm seas.

KEY TO GENERA.

a. Thallus consisting of a flat disk ....*b*.
  b. Thallus, thin, composed of a single undifferentiated layer ....1. Melobesia (p. 523).
  bb. Thallus thick, composed of a thin lower layer and a thicker upper layer, tetrasporangia borne on the sides of the conceptacle ....2. Dermatolithon (p. 524).

aa. Thallus consisting of an irregularly spreading, calcareous mass incrusting stones, coral, or other algæ...*c.*

c. Mature tetrasporangial conceptacle having a separate opening for each sporangium ....3. Lithothamnium (p. 524).

cc. Mature tetrasporangial conceptacle having a single opening through which all the sporangia discharge, vegetative tissues usually in fairly regular layers. .4. Lithophyllum (p. 525).

aaa. Thallus erect, segmented, branched...*d.*

d. Cystocarps forming wartlike protuberances, scattered over the surface of the segments..5. Amphiroa (p. 526).

dd. Cystocarps immersed in the swollen apices of some segments...............6. Corallina (p. 527).

Genus 1. **Melobesia** Lamouroux.

Melobesia, Lamouroux, 1816, p. 313.

Thallus forming a small, flattened disk, attached to the substratum by the entire under surface, strongly incrusted with lime, composed of a single, undifferentiated stratum, consisting of numerous rows of cells disposed in a radiating, fanlike arrangement, with larger, more-elongated cells (so-called "hair cells" or "heterocysts") present among the ordinary cells; tetrasporangia zonately divided, borne in flask-shaped conceptacles formed by the separation of thallus cells, these conceptacles borne superficially or somewhat immersed in locally thickened portions, opening to the exterior by a single central pore, or by a separate pore situated above each tetrasporangium; antheridial and cystocarpic conceptacles flask-shaped, superficial or somewhat immersed, opening by single, central pores.

About 20 species, widely distributed, especially in warm seas.

The group of algæ including this and related genera has been differently arranged by different authors and has recently been extensively divided. There is at present little uniformity in the treatment of the forms included in this group, and it seems probable that further work will change the arrangement proposed by present authors.

Melobesia farinosa Lamouroux.

Melobesia farinosa, Lamouroux, 1816, p. 315.
Melobesia farinosa, Farlow, 1882, p. 180.
Melobesia farinosa, De Toni, 1905, p. 1764.
P. B.-A. Nos. 200, 1549.

Frond forming small, thin, flat, more or less rounded disks, 1 to 5 mm. in diameter, surface farinaceous, irregularly rimose from the center to the periphery, composed of a single stratum except in the vicinity of conceptacles; conceptacles scattered over the frond, 0.1 to 0.2 mm. in diameter, rather inconspicuous, opening by single central pores surrounded by elongated cells, but not conspicuously bordered by cilia.

Generally distributed in all seas.

Abundant on other algæ on Bogue Beach, Beaufort, N. C., abundant on *Sargassum filipendula* dredged from coral reef offshore, July to August, 1915, probably at other times also.

Forma **callithamnioides** (Falkenberg) Foslie. Fig. 47.

Melobesia callithamnioides, Falkenberg, 1879, p. 265.
Melobesia callithamnioides, De Toni, 1905, p. 1765.
Melobesia farinosa f. *callithamnioides*, Foslie, 1905, p. 96.

Fronds very variable, consisting of creeping, closely adherent, dichotomously branched filaments which are sometimes considerably elongated, often spreading out toward the apices and coalescent into more or less dense structures broken by more or less numerous interspaces, sometimes forming more or less complete dichotomously radiating disks, closely adherent by the entire lower surface; conceptacles of the same size as in the species, but rarer, the form being mostly sterile.

Naples; Adriatic Sea.

Fairly abundant on various algæ dredged from the coral reef offshore, Beaufort, N. C., August, 1914.

As found in Europe, the form grades over into the species, but in this region it seems, while approaching the habit of the species, to remain distinct.

This form has not previously been reported from North America.

Another species, *M. lejolisii* Rosanoff, a more northern species than the above, may be found within our range, but has not been observed by the author. This is distinguished from the present species by the absence of "heterocysts" in the frond and the presence of conspicuous cilia bordering the openings of the conceptacles.

The only other species recorded for this region that is likely to be mistaken for the above is *Dermatolithon pustulatum* (Lamour.) Foslie. The latter is distinguished by its thicker frond and larger, more conspicuous conceptacles.

Genus 2. **Dermatolithon** Foslie.

Dermatolithon, Foslie, 1900, p. 21.

Thallus forming a small, flattened disk, attached to the substratum by the entire under surface, strongly incrusted with lime, composed of two distinct strata, the lower, a thin hypothallium, usually consisting of a single layer of elongated cells, and the upper, a thicker perithallium, consisting of several layers of cells; tetraspongia borne in flask-shaped conceptacles somewhat immersed in locally thickened portions, each conceptacle opening to the exterior by an apical pore; sporangia borne only on the sides of the conceptacle, the middle being occupied by paraphyses; cystocarps borne in flask-shaped, somewhat immersed conceptacles opening by apical pores, carpospores accompanied by paraphyses.

About 10 species, generally distributed, especially in warm seas.

Dermatolithon pustulatum (Lamouroux) Foslie.

Melobesia pustulata, Lamouroux, 1816, p. 315, pl. 12, f. c, B.
Melobesia pustulata, Farlow, 1882, p. 181.
Dermatolithon pustulatum, Foslie, 1900, p. 21.
Dermatolithon pustulatum, De Toni, 1905, p. 1771.
P. B.-A. No. 300 (Melobesia farinosa).

Frond forming rather small, rather thick, flat, rather rounded more or less confluent disks, 2 to 10 mm. in diameter, surface not farinaceous, composed of two differentiated strata, hypothallium consisting of vertically elongate cells, perithallium consisting of rather square cells, "heterocysts" lacking; conceptacles large, conspicuous, 0.3 to 0.5 mm. in diameter, scattered over the thallus, opening by single, central pores, not bordered by cilia.

Widely distributed.

Very abundant on *Zostera marina* and often on other algæ throughout the harbor and on Bogue Beach, Beaufort, N. C.

This species often occurs in pure growths almost covering the leaves of Zostera. It is distinguished from *Melobesia farinosa*, the only other species observed here with which it is likely to be confused, by its thicker frond, its larger, more conspicuous conceptacles, and the absence of "heterocysts."

Genus 3. **Lithothamnium** Philippi.

Lithothamnium, Philippi, 1837, p. 387.

Thallus forming a more or less irregular incrusting mass, attached to the substratum by the entire under surface, frequently giving off from this base more or less numerous wartlike, stemlike, or corallike outgrowths of various, frequently irregular, shapes, strongly incrusted with lime, composed of two strata, cells more or less regularly arranged; tetrasporangia borne in superficial or somewhat sunken conceptacles, each sporangium opening to the exterior by a separate pore, sporangia zonately divided; antheridia and cystocarps borne in more or less conical, superficial, or slightly sunken conceptacles, each conceptacle opening by a single apical pore, carpospores arising from the periphery of the fusion cell, the central part of the fusion cell bearing a few elongated, evanescent paraphyses; antheridia and cystocarps apparently borne on different plants.

About 80 species, widely distributed, mostly in warm seas.

This genus has been variously characterized by different authors and is still not well understood. It is distinguished from Lithophyllum chiefly by the fact that each sporangium communicates with the exterior by a separate pore, so that the surface of a mature tetrasporangial conceptacle, when viewed with a lens, looks like a miniature pepperbox. The species are exceedingly difficult and can be determined only by those who are familiar with them or by comparison with authentic specimens. In some cases the same species seems to show different forms on different substrata.

Lithothamnium sejunctum Foslie (?).

Lithothamnion sejunctum, Fosile, 1906, p. 3.

Thallus disk shaped, almost spherical, later confluent and irregular, rather thick, forming masses incrusting stones, etc., strongly calcified and closely attached to the substratum, showing slight, concentric zonation; composed of two distinct strata, the lower (hypothallium) composed of several layers of cells about 11 to 18 by 5 to 9 mic., the upper (perithallium) composed of several layers of cells, these cells squarish, 5 to 7 mic. in diameter or slightly vertically elongated, sometimes slightly horizontally elongated; tetrasporangial conceptacles embedded, hemispherical, 160 to 260 mic. in diameter, bearing about 40 pores; cystocarpic conceptacles hemisph ericalconical, 200 to 300 mic. in diameter.

West Indies.

Incrusting coral rock dredged from coral reef offshore, Beaufort, N. C., May, 1907 (?).

To this species is referred, with some doubt, an antheridial plant incrusting a part of one piece of coral rock, but the determination can not be made with assurance, since no authentic specimen has been available for comparison. It does not seem to belong to any other described species, and has not seemed to deserve description as a new species. It is probable that much of the coral rock dredged from the reef bears this plant, but only one piece has been available for examination. On this piece the plant here referred to occurs alongside *Lithophyllum intermedium*. From the latter species it is distinguished with difficulty. As found here, it has a slightly rougher, less glistening surface than the Lithophyllum. In section the two strata are more sharply defined than in the latter form. This species has not been recorded elsewhere outside of the West Indies.

Genus 4. **Lithophyllum** Philippi.

Lithophyllum, Philippi, 1837, p. 387.

Thallus forming a more or less irregular incrusting mass, more or less closely attached to the substratum, margin free or loosely attached, undivided or variously lobed, sometimes bearing irregular proliferations, strongly incrusted with lime, composed of two strata, cells rather regularly arranged, radiating toward the periphery, those in the upper perithallium smaller than in the lower hypothallium; tetrasporangia borne in sunken or somewhat prominent conceptacles, these conceptacles hemispherical-conical, at first convex, then losing more or less of the cortex, becoming somewhat depressed, the entire conceptacle communicating with the exterior by a single central pore; cystocarps borne in sunken or somewhat prominent, convex conceptacles, carpospores accompanied by a central mass of short paraphyses.

About 50 species, mostly in warm seas.

This genus has been variously characterized by different authors and is still not well understood. It is distinguished from Lithothamnium chiefly by the fact that the entire tetrasporangial conceptacle communicates with the exterior by a single apical pore; in most cases, at least, the cells also are arranged in more regular layers than in Lithothamnium. The species are exceedingly difficult and can be determined only by those who are familiar with them or by comparison with authentic specimens.

Lithophyllum intermedium Foslie.

Lithophyllum intermedium, Foslie, 1906, p. 23.

Thallus disk shaped, almost spherical, later irregular, up to about 3 mm. thick, forming masses incrusting stones, etc., more or less closely attached by the under surface, bowl shaped or irregular, edges scalloped or irregular; showing two distinct strata, the lower (hypothallium) weakly or strongly developed, composed of several or many layers of cells 11 to 25 by 7 to 11 mic., the upper (perithallium) composed of several layers of cells almost always vertically elongated, 9 to 22 (usually 9 to 18) mic. long and 7 to 11 mic. broad; tetrasporangial conceptacles somewhat convex, not sharply defined, 150 to 250 or up to 300 mic. diameter.

Florida; West Indies.

Incrusting coral rock dredged from coral reef offshore, Beaufort, N. C., May, 1907, one small sterile plant on base of *Sargassum filipendula* dredged from coral reef, July, 1915.

This species will not be mistaken for any other found in this region except *Lithothamnium sejunctum* (?). From the latter it is distinguished with difficulty. As found here it has a slightly smoother, more glistening surface, and in section the two strata are less sharply defined than in the Lithothamnium. It is probable that much of the coral rock dredged from the reef bears this plant, but only one piece has been available for examination. On this it occurs alongside *Lithothamnium sejunctum* (?), and bears numerous tetrasporangial conceptacles. This is the northern known limit for the species and the genus.

Genus 5. **Amphiroa** Lamouroux.

Amphiroa, Lamouroux, 1812, p. 186.

Thallus erect, usually arising from a small basal disk, terete or more or less flattened, segmented, dichotomously, trichotomously, or verticillately branched, strongly calcified except at the more or less elongated joints; composed of elongated cells arranged in superimposed transverse zones surrounded, except at the joints, by a layer of smaller cortical cells; conceptacles small, scattered over the surface of the segments, immersed in the cortex or more or less prominent, opening by apical pores; tetrasporangia zonately divided.

About 30 species, in warm seas.

KEY TO SPECIES.

Segments of thallus terete or nearly so, frond strongly calcified and very brittle. 1. *A. fragilissima* (p. 526).
Segments of thallus decidedly flattened, often two or three times as broad as thick, frond less calcified and less brittle .... 2. *A. brasiliana* (p. 527).

1. **Amphiroa fragilissima** (Linnæus) Lamouroux. Pl. CXII, fig. 4c.

Corallina fragilissima, Linnæus, 1758, vol. 1, p. 806.
Amphiroa fragilissima, Lamouroux, 1816, p. 298.
Amphiroa fragilissima, De Toni, 1905, p. 1808.
P. B.-A. No. 2198.

Fronds forming tufts, 2 to 5 cm. tall, about 0.2 to 1 mm. in diameter, usually terete, sometimes flattened, especially toward the apices, branching dichotomous, sometimes irregular, segments 6 to 14 diameters long, usually 8 to 10 diameters, sometimes locally swollen; conceptacles scattered over the surface of the segments, inconspicuous; color pinkish white, becoming white when dried; texture very fragile.

West Indies; Peru.

Occasional on Bogue Beach, Beaufort, N. C., summer and autumn, 1903 to 1905; one plant Shackleford jetty, August, 1905; about 10 tufts, coral reef offshore, May, 1907.

The specimens from the coral reef and the plant from Shackleford jetty seem to agree with this species from other localities, except that they show slightly greater flattening. Some of the specimens from Bogue Beach are decidedly coarser and wider, but the differences do not seem sufficiently great to warrant placing them in another species.

This species will not be confused with any other found in this region except *A. brasiliana*. From the latter it is distinguished by its more calcified, more brittle frond, with the segments terete or nearly so.

This is the northern known limit of the species and of the genus.

2. **Amphiroa brasiliana** Decaisne.

Amphiroa brasiliana, Decaisne, 1842 a, p. 125.
Amphiroa brasiliana, De Toni, 1905, p. 1817.

Frond forming tufts, 1 to 5 cm. tall, segments decidedly flattened, about 0.5 to 1.2 mm. wide, often two to three times as wide as thick, lower segments cuneate or quadrate, upper ones linear-obtuse; branching dichotomous; color dirty white; texture moderately fragile.

Brazil.

One fairly large tuft dredged from coral reef offshore, Beaufort, N. C., August, 1915.

The plants found here can not be determined with certainty because of the lack of authentic material for comparison. They seem, however, to belong to this species, judging from the descriptions and a photograph of the original material. This species is distinguished from the preceding by its less calcified, less brittle fronds, with decidedly flattened segments. It is not known elsewhere outside of Brazilian waters, unless this species is identical with some described under other names.

Genus 6. **Corallina** Linnæus.

Corallina, Linnæus, 1758, tom. 1, p. 805 (in part).

Thallus erect, usually arising from a small basal disk, terete or flattened, segmented, branching dichotomous or lateral, more or less abundant and usually in one plane, strongly calcified except at the more or less elongated joints; medullary portion more or less plainly transversely zonate, composed of compact, segmented, branched filaments, cortex composed of a few layers of small cells, becoming smaller toward the surface, cortex lacking at the joints; conceptacles occurring in the swollen apices of segments or filling the segments, sunken in the medullary layer, forming more or less prominent protuberances, opening by single apical pores; tetrasporangia zonately divided.

About 40 species, mostly in warm seas.

KEY TO SPECIES.

Frond 4 to 8 mm. tall, about 0.1 to 0.2 mm. in diameter, branching regularly dichotomous .... 1. *C. capillacea* (p. 527).

Frond 1 to 2.5 cm. tall, about 0.2 to 0.7 mm. in diameter, branching partly pinnate, often bearing numerous opposite distichous branchlets .... 2. *C. cubensis* (p. 528).

1. **Corallina capillacea** (Harvey) comb. nov. Pl. CXIV, fig. 6.

Jania capillacea, Harvey, 1853, p. 84.
P. B.-A. No. 150 (Jania capillacea).

Frond erect, capillary, about 4 to 8 mm. tall, 0.1 to 0.2 mm. in diameter, branching regularly dichotomous; conceptacles formed as flattened swellings at or near the ends of the ultimate branches, opening by a distinct apical pore; from the upper edges of these conceptacles there arise branches (usually two) as continuations of the frond; carpospores club shaped, arising in a compact group from base of conceptacle; tetrasporangia zonately divided, arising in a compact group from base of conceptacle.

Florida; West Indies; Bermuda.

One small mass on *Sargassum sp.*, Bogue Beach, Beaufort, N. C., August, 1903, two to three plants on coral reef offshore, May, 1907.

This species is easily distinguished from the following one by its smaller size, its more regularly dichotomous branching, and its production of hornlike branches from the upper edges of the conceptacles. It will not be mistaken for any other occurring in this region.

This is the northern known limit of the species.

2. **Corallina cubensis** (Montagne) Kuetzing. Pl. CXIII, figs. 4 and 5.

Jania cubensis, Montagne, in Kuetzing, 1849a, p. 709.
Jania cubensis, Harvey, 1853, p. 84.
Corallina cubensis, Kuetzing, 1858, Bd. 8, p. 37, pl. 77, f. II.
Jania cubensis, De Toni, 1905, p. 1857.
P. B.-A. No. 1500.

Frond erect, forming dense, intricate tufts, 1 to 2.5 cm. tall, about 0.2 to 0.7 mm. in diameter, branching dichotomous or subpinnate, branches spreading, sometimes naked, usually clothed with short, fine, simple, or sometimes forked branchlets arising oppositely in two rows, branchlets sometimes prolonged, segments of the frond subcylindrical below, more cuneate above; texture fragile; color dirty, whitish pink.

Florida; West Indies.

Few fairly large tufts dredged from the coral reef offshore, Beaufort, N. C., August, 1914, and July to August, 1915.

This species is easily distinguished from the preceding by its larger size, its more pinnate branching, and its opposite branchlets in two rows.

This is the northern known limit of the species.

Undetermined species.

A few species have been found in quantities or condition insufficient for determination. One of these (No. 1, Pl. CXII, fig. 5) seems deserving of comment. This is a red alga with an upright thallus, 6.5 cm. tall, shortly stipitate and attached by a small disk; it is flat and thin, being 4 to 13 mm. wide, irregularly branched and bearing minute proliferations from the margins and from the wider apices; the structure closely resembles that of *Halymenia floridana*, having the "stellate ganglia" in subepidermal view as found in that species; the texture is thin membranaceous, the color brownish red; no fruit is present. This specimen seems to be closely related to *Halymenia floridana*, but because of the difference in form and color and the absence of fruit, it has seemed best to keep it separate from that species.

SUMMARY OF ALGAL FLORA.

	Families.	Genera.	Species.	Varieties.	Per cent.	Identified species and varieties.	Per cent.
Myxophyceæ	5	10	12	....	8.5	10	7.5
Chlorophyceæ	8	13	23	2	17.6	25	18.8
Phæophyceæ	8	18	27	2	20.4	27	20.3
Rhodophyceæ	12	43	74	2	53.5	71	53.4
Total	33	84	136	6	....	133	....

TABLES.

TABLE 1.—SPECIES FOUND IN BEAUFORT HARBOR.

Summer Flora:
- MYXOPHYCEÆ—
  - Chroococcus turgidus?
  - Hydrocoleum lyngbyaceum.
  - Lyngbya lutea.
  - Oscillatoria nigro-viridis.
- CHLOROPHYCEÆ—
  - Ulva fasciata.
  - Chætomorpha linum.
  - Chætomorpha linum f. aerea.
  - Chætomorpha brachygona.
  - Cladophora crystallina.
  - Codium decorticatum.
  - Codium tomentosum.
- PHÆOPHYCEÆ—
  - Ectocarpus duchassaingianus.
  - Ectocarpus mitchellæ.
  - Rosenvingea orientalis.
  - Dictyopteris polypodioides.
  - Dictyota dichotoma.
  - Padina vickersiæ.
  - Spatoglossum schrœderi.
- RHODOPHYCEÆ—
  - Erythrotrichia carnea.
  - Erythrocladia recondita.
  - Goniotrichum alsidii.
  - Acrochætium dufourii.
  - Achrochætium hoytii.
  - Acrochætium parvulum.
  - Gelidium coerulescens.[a]
  - Actinococcus aggregatus.
  - Eucheuma gelidium.
  - Gracilaria confervoides.
  - Champia parvula.[a]
  - Lomentaria uncinata.[a]
  - Rhodymenia palmetta.
  - Nitophyllum medium.
  - Chondria dasyphylla.
  - Chondria sedifolia.[a]
  - Chondria atropurpurea?
  - Herposiphonia tenella.
  - Laurencia tuberculosa var. gemmifera.
  - Polysiphonia harveyi.
  - Polysiphonia denudata.
  - Callithamnion polyspermum.
  - Ceramium tenuissimum?
  - Grateloupia filicina.
  - Amphiroa fragilissima.
  - Dermatolithon pustulatum.

Spring Flora:
- CHLOROPHYCEÆ—
  - Enteromorpha prolifera.
  - Enteromorpha flexuosa.
  - Enteromorpha intestinalis.
  - Enteromorpha linza.
  - Chætomorpha melagonium f. rupincola.
  - Cladophora flexuosa.
  - Rhizoclonium riparium.
  - Bryopsis plumosa.
- PHÆOPHYCEÆ—
  - Ectocarpus confervoides.
  - Ectocarpus siliculosus.
  - Petalonia fascia.
  - Leathesia difformis.
  - Myrionema strangulans.
  - Stilophora rhizodes.
- RHODOPHYCEÆ—
  - Bangia fusco-purpurea.
  - Porphyra leucosticta.
  - Acrochætium corymbiferum.
  - Gelidium coerulescens.[b]
  - Champia parvula.[b]
  - Lomentaria uncinata.[b]
  - Grinnellia americana.
  - Chondria sedifolia.[b]
  - Chondria tenuissima var. baileyana.
  - Dasya pedicellata.
  - Polysiphonia nigrescens.
  - Ceramium strictum.

Perennial Species:
- MYXOPHYCEÆ—
  - Lyngybya confervoides?
- CHLOROPHYCEÆ—
  - Enteromorpha prolifera.
  - Ulva lactuca (both varieties?).
- PHÆOPHYCEÆ—
  - Fucus vesiculosus.
  - Sargassum filipendula.
- RHODOPHYCEÆ—
  - Acrochætium virgatulum.
  - Gelidium crinale?
  - Gymnogongrus griffithsiæ
  - Agardhiella tenera.
  - Gracilaria multipartita.
  - Hypnea musciformis.

TABLE 2.—SPECIES FOUND ON CORAL REEF.

- MYXOPHYCEÆ:
  - Microchæte nana.[c]
  - Phormidium sp.[c]
- CHLOROPHYCEÆ:
  - Cladophora sp.
  - Derbesia turbinata.[c]
  - Codium tomentosum.
  - Udotea cyathiformis.[c]
- PHÆOPHYCEÆ:
  - Ectocarpus sp.
  - Phæostroma pusillum.[c]
  - Streblonema solitarium.[c]
  - Elachistea stellulata.[c]
  - Sporochnus pedunculatus.[c]
  - Sargassum filipendula.
  - Dictyopteris polypodioides.

[a] Occurs in the spring also.

[b] Occurs in summer also.

[c] Found growing in this region only on coral reef.

Table 2.—Species Found on Coral Reef—Continued.

Phæophyceæ—Continued.
- Dictyopteris serrata.[a]
- Dictyota dichotoma.
- Spatoglossum schrœderi.
- Zonaria flava.[a]

Rhodophyceæ:
- Erythrocladia recondita.
- Erythrocladia vagabunda.[a]
- Goniotrichum alsidii.
- Acrochætium affine.[a]
- Acrochætium infestans.[a]
- Agardhiella tenera.
- Meristotheca duchassaingii.[a]
- Gracilaria confervoides.
- Hypnea musciformis.
- Champia parvula.
- Chrysymenia agardhii.[a]
- Chrysymenia enteromorpha.[a]
- Chrysymenia uvaria.[a]
- Lomentaria rosea.[a]
- Rhodymenia palmetta.
- Grinnellia americana.
- Nitophyllum medium.

Rhodophyceæ—Continued.
- Brongniartella mucronata.[a]
- Chondria dasyphylla.
- Chondria sedifolia.
- Dasya pedicellata.
- Polysiphonia sp.
- Ceramium strictum.
- Callithamnion sp.
- Spermothamnion investiens.[a]
- Spyridia clavata.[a]
- Spyridia filamentosa.[a]
- Griffithsia sp.[a]
- Halymenia gelinaria.[a]
- Halymenia agardhii.[a]
- Amphiroa fragilissima.
- Amphiroa brasiliana.[a]
- Corallina capillacea.[a]
- Corallina cubensis.[a]
- Melobesia farinosa.[a]
- Melobesia farinosa f. callithamnioides.[a]
- Lithothamnium sejunctum (?).[a]
- Lithophyllum intermedium.[a]

Table 3.—Species Found at Beaufort only on Bogue Beach.

Myxophyceæ:
- Dichothrix penicillata.

Chlorophyceæ:
- Cladophora prolifera.
- Endoderma viride.
- Caulerpa prolifera.

Phæophyceæ:
- Streblonema invisibile.
- Castagnea zosteræ.
- Sargassum natans.
- Sargassum natans f. angustum.
- Sargassum filipendula var. montagnei.
- Sargassum sp.
- Zonaria variegata.

Rhodophyceæ:
- Rhabdonia ramosissima.
- Agardhinula browneæ.
- Chondria littoralis.
- Chondria sp.
- Laurencia sp.
- Polysiphonia havanensis.
- Ceramium rubrum.
- Cryptonemia crenulata.
- Halymenia floresia.
- Halymenia floridana.
- Undetermined species No. 1.

Table 4.—Species Found Only at Places Other than Beaufort.

Ocracoke, N. C.:
- Lyngbya semiplena.
- Microcoleus chthonoplastes.
- Plectonema battersii.
- Spirulina sp.
- Ulvella lens.
- Gomontia polyrhiza.

Southport, N. C.:
- Cladophora fascicularis.
- Bostrychia rivularis.

Charleston, S. C.:
- Grateloupia gibbesii.

Port Royal, S. C.:
- Gracilaria multipartita var. angustissima.

Table 5.—Species Reaching in this Region their Northern Known Limit on our Coast.

Beaufort, N. C.:
- Harbor; summer flora—
  - Ulva fasciata.
  - Chætomorpha brachygona.
  - Codium decorticatum.[b]
  - Codium tomentosum.[b]
  - Ectocarpus duchassaingianus.
  - Rosenvingea orientalis.[b]
  - Dictyota dichotoma.[b]
  - Padina vickersiæ.[b]
  - Spatoglossum schrœderi.[b]
  - Gelidium cœrulescens.
  - Rhodymenia palmetta.
  - Chondria atropurpurea.

Beaufort, N. C.—Continued.
- Harbor: summer flora—Continued.
  - Herposiphonia tenella.[b]
  - Laurencia tuberculosa var. gemmifera.[b]
  - Grateloupia filicina.[b]
  - Amphiroa fragilissima.[b]
- Coral reef—
  - Udotea cyathiformis.[b]
  - Zonaria flava.[b]
  - Meristotheca duchassaingii.[b]
  - Chrysymenia agardhii.[b]
  - Chrysymenia enteromorpha.[b]
  - Chrysymenia uvaria.[b]
  - Brongniartella mucronata.[b]

[a] Found growing in this region only on coral reef.

[b] Northern known limit of genus on our coast.

TABLE 5.—SPECIES REACHING IN THIS REGION THEIR NORTHERN KNOWN LIMIT ON OUR COAST—Con.

Beaufort, N. C.—Continued.
- CORAL REEF—Continued.
  - Spyridia clavata.
  - Spermothamnion investiens.
  - Halymenia gelinaria.[a]
  - Halymenia agardhii.[a]
  - Amphiroa brasiliana.[a]
  - Lithothamnium sejunctum (?).[a]
  - Lithophyllum intermedium.[a]
  - Corallina capillacea.
  - Corallina cubensis.
- BOGUE BEACH—
  - Dichothrix penicillata.
  - Caulerpa prolifera.[a]
  - Castagnea zosteræ.
  - Zonaria variegata.[a]

Beaufort, N. C.—Continued.
- BOGUE BEACH—Continued.
  - Rhabdonia ramosissima.[a]
  - Agardhinula browneæ.[a]
  - Chondria littoralis.
  - Polysiphonia havanensis.
  - Cryptonemia crenulata.[a]
  - Halymenia floresia.[a]
  - Halymenia floridana.[a]

Other localities:
- SOUTHPORT, N. C.—
  - Cladophora fascicularis.
- OCRACOKE, N. C.—
  - Eucheuma gelidium.[a]
- CHARLESTON, S. C.—
  - Grateloupia gibbesii.

TABLE 6.—SPECIES REACHING IN THIS REGION THEIR SOUTHERN KNOWN LIMIT ON OUR COAST.

Beaufort, N. C.:
- HARBOR—
  - Spring flora—
    - Chætomorpha melagonium f. rupincola.
    - Leathesia difformis.[b]
    - Stilophora rhizodes.[b]
    - Chondria tenuissima var. baileyana.
    - Ceramium strictum.
  - Summer flora—
    - Polysiphonia harveyi.[c]

Beaufort, N. C.—Continued.
- HARBOR—Continued.
  - Perennial species—
    - Fucus vesiculosus.[b]
- CORAL REEF—
  - Lomentaria rosea.

Ocracoke, N. C.:
- Plectonema battersii.

TABLE 7.—SPECIES NEW TO NORTH AMERICA.

Beaufort, N. C.:
- HARBOR—
  - Dictyopteris polypodioides.[a]
  - Erythrocladia recondita.[d]
  - Acrochætium dufourii.[d]
  - Acrochætium hoytii.[d]
  - Acrochætium parvulum.
  - Nitophyllum medium.[a, d]
- CORAL REEF—
  - Microchæte nana.[d]
  - Derbesia turbinata.[d]
  - Phæostroma pusillum.[d]
  - Streblonema solitarium.
  - Elachistea stellulata.[b]
  - Sporochnus pedunculatus.[a]

Beaufort, N. C.—Continued.
- CORAL REEF—Continued.
  - Dictyopteris polypodioides.[a]
  - Dictyopteris serrata.[a]
  - Erythrocladia recondita.[d]
  - Erythrocladia vagabunda.[d]
  - Acrochætium affine.[d]
  - Acrochætium infestans.[d]
  - Nitophyllum medium.[a,d]
  - Melobesia farinosa f. callithamnioides.
  - Amphiroa brasiliana(?).
- BOGUE BEACH—
  - Streblonema invisibile.[d]

Ocracoke, N. C.:
- Ulvella lens.

[a] Northern known limit of genus on our coast.
[b] Southern known limit of genus on our coast.
[c] Possibly at Port Royal, S. C.
[d] Species first described from this region.

TABLE 8.—DISTRIBUTION OF BEAUFORT AND ADJACENT SPECIES IN VARIOUS REGIONS.[a]

[Occurrence indicated by cross (×).]

	Northern New England.	Southern New England.	Florida-West Indies region.	Europe.	Pacific coast of North America.
MYXOPHYCEÆ.					
Chroococcus turgidus	×	×	×	×	×
Lyngbya confervoides	......	×	×	×	×
Lyngbya semiplena	×	×	×	......	×
Lyngbya lutea	×	×	×	×	......
Oscillatoria nigro-viridis	×	......	......	......	×
Hydrocoleum lyngbyaceum	×	×	×	×	×
Microcoleus chthonoplastes	×	×	×	×	×
Microchæte nana	......	......	......	......	......
Plectonema battersii	......	......	×	×	......
Dichothrix pencillata	......	......	×	×	......
CHLOROPHYCEÆ.					
Ulva fasciata	......	......	×	×	×
Ulva lactuca var. rigida	×	×	×	×	×
Ulva lactuca var. latissima	×	×	×	×	×
Enteromorpha linza	×	×	......	×	×
Enteromorpha prolifera	×	×	×	×	×
Enteromorpha intestinalis	×	×	×	×	×
Enteromorpha flexuosa	......	......	×	×	×
Endoderma viride	......	......	×	×	......
Ulvella lens	......	......	×	×	......
Chætomorpha brachygona	......	......	×	......	......
Chætomorpha linum	×	×	×	×	×?
Chætomorpha linum f. aerea	×	×	×	×	×
Chætomorpha melagonium f. rupincola	×	×	......	......	×
Rhizoclonium riparium	×	×	×	×	×
Cladophora flexuosa	×	×	......	×	×?
Cladophora crystallina	......	......	×	×	......
Cladophora fascicularis	......	......	×	×	......
Cladophora prolifera	......	......	×	×	×
Gomontia polyrhiza	×	×	×	×	×
Bryopsis plumosa	×	×	×	×	×?
Derbesia turbinata	......	......	......	......	......
Codium tomentosum	......	......	×	×	......
Codium decorticatum	......	......	×	×	......
Udotea cyathiformis	......	......	×	......	......
Caulerpa prolifera	......	......	×	×	...
PHÆOPHYCEÆ.					
Ectocarpus mitchellæ	......	×	×	×	×
Ectocarpus duchassaingianus	......	......	×	......	......
Ectocarpus siliculosus	×	×	......	×	×
Ectocarpus confervoides	×	×	......	×	×
Streblonema invisibile	......	......	......	......	......
Streblonema solitarium	......	......	......	×	......
Phæostroma pusillum	......	......	......	......	......
Petalonia fascia	×	×	......	×	×
Rosenvingea orientalis	......	......	×	×	×
Elachistea stellulata	......	......	......	×	......
Castagnea zosteræ	......	......	×	×	......
Myrionema strangulans	×	×	......	×	×
Leathesia difformis	×	×	......	×	×
Stilophora rhizodes	......	×	......	×	......
Sporochnus pedunculatus	......	......	......	×	......
Fucus vesiculosus	×	×	......	×	......
Sargassum natans	......	×	×	......	......
Sargassum natans f. angustum	......	×	×	......	......
Sargassum filipendula	......	×	×	......	......
Sargassum filipendula var. montagnei	......	×	×	......	......
Zonaria flava	......	......	×	×	......
Zonaria variegata	......	......	×	......	......
Padina vickersiæ	......	......	×	×	......
Spatoglossum schroederi	......	......	×	......	......
Dictyopteris polypodioides	......	......	......	×	......
Dictyopteris serrata	......	......	......	......	......
Dictyota dichotoma	......	......	×	×	......
RHODOPHYCEÆ.					
Erythrocladia recondita	......	......	......	......	......
Erythrocladia vagabunda	......	......	......	......	......
Bangia fusco-purpurea	×	×	......	×	×
Goniotrichum alsidii	......	×	×	×	......
Erythrotrichia carnea	×	×	×	×	×
RHODOPHYCEÆ—continued.					
Porphyra leucosticta	......	×	×	×	×
Acrochætium infestans	......	......	......	......	......
Acrochætium parvulum	......	......	......	×	......
Acrochætium dufourii	......	......	......	......	......
Acrochætium hoytii	......	......	......	......	......
Acrochætium affine	......	......	......	......	......
Acrochætium virgatulum	×	×	......	×	......
Acrochætium corymbiferum	......	......	......	×	×
Gelidium coerulescens	......	......	×	......	......
Gelidium crinale	×	×	×	×	×
Gymnogongrus griffithsiæ	......	×	......	×	......
Actinococcus aggregatus	......	×	......	×	......
Agardhiella tenera	×	×	×	......	×
Rhabdonia ramosissima	......	......	×	......	......
Eucheuma gelidium	......	......	×	......	......
Meristotheca duchassaingii	......	......	×	......	......
Gracilaria confervoides	......	×	×	×	×
Gracilaria multipartita	......	×	×	×	......
Gracilaria multipartita var. angustissima	×	×	×	×	......
Hypnea musciformis	......	×	×	×	......
Rhodymenia palmetta	......	......	×	×	......
Agardhinula browneæ	......	......	×	......	......
Chrysymenia enteromorpha	......	......	×	......	......
Chrysymenia agardhii	......	......	×	......	......
Chrysymenia uvaria	......	......	×	×	......
Champia parvula	×	×	×	×	......
Lomentaria uncinata	×	×	×	×	......
Lomentaria rosea	×	×	......	......	......
Nitophyllum medium	......	......	......	......	......
Grinnellia americana	×	×	×	......	......
Laurencia tuberculosa var. gemmifera	......	......	×	......	......
Chondria dasyphylla	......	×	×	×	......
Chondria littoralis	......	......	×	......	......
Chondria atropurpurea ?	......	......	×	......	......
Chondria sedifolia	......	×	×	......	......
Chondria tenuissima var. baileyana	×	×	......	......	......
Polysiphonia harveyi	×	×	×	......	......
Polysiphonia denudata	×	×	......	×	......
Polysiphonia havanensis	......	......	×	......	......
Polysiphonia nigrescens	×	×	......	×	......
Herposiphonia tenella	......	......	×	×	......
Dasya pedicellata	×	×	×	×	......
Brongniartella mucronata	......	......	×	......	......
Bostrychia rivularis	......	×	×	......	......
Spermothamnion investiens	......	......	×	......	......
Callithamnion polyspermum	......	......	×	×	×
Spyridia filamentosa	×	×	×	×	×
Spyridia clavata	......	......	×	......	......
Ceramium rubrum	×	×	......	×	×?
Ceramium strictum	×	×	×	×	......
Ceramium tenuissimum	×	×	×	×	×
Halymenia floresia	......	......	×	×	×?
Halymenia agardhii	......	......	×	......	......
Halymenia gelinaria	......	......	×	......	......
Halymenia floridana	......	......	×	......	......
Grateloupia filicina	......	......	×	×	......
Grateloupia gibbesii	......	......	......	......	......
Cryptonemia crenulata	......	......	×	......	......
Amphiroa fragilissima	......	......	×	......	......
Amphiroa brasiliana	......	......	......	......	......
Lithothamnium sejunctum ?	......	......	×	......	......
Lithophyllum intermedium	......	......	×	......	......
Corallina capillacea	......	......	×	......	......
Corallina cubensis	......	......	×	......	......
Melobesia farinosa	×	×	×	×	......
Melobesia farinosa f. callithamnioides	......	......	......	×	......
Dermatolithon pustulatum	×	×	×	×	×
Total	45	61	93	78	41

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[a] The data for this table were obtained from the distribution of the various species given by De Toni (1889–1907); from the lists of Collins for New England (1900), Jamaica (1901), and Vancouver Island (1913), of Hauck for Porto Rico (1888 a), of Börgesen for the Virgin Islands (Danish West Indies) (1913–1919), of Setchell and Gardner for northwestern America (1903), and of Saunders for Alaska (1901); and from information kindly furnished by Mr. Frank S. Collins and Dr. Marshall A. Howe.

Table 9.—Surface Temperature of Water at 5 p. m. off Laboratory Wharf, Beaufort, N. C.

[Expressed in degrees centigrade.]

Month.	1907			1908			1909		
	Maximum.	Minimum.	Average.	Maximum	Minimum.	Average	Maximum.	Minimum.	Average.
January	......	......	......	12.0	5.0	9.0	15.5	7.8	11.0
February	......	......	......	12.8	3.9	8.5	16.7	5.5	11.0
March	......	......	......	19.5	10.0	14.5	16.0	10.0	13.3
April	......	......	......	21.7	16.0	19.0	22.8	13.9	16.7
May	......	......	......	26.7	18.9	23.3	25.5	18.3	22.0
June	......	......	......	28.3	24.5	26.7	29.5	23.9	26.7
July	......	......	......	31.0	25.0	28.5	31.0	25.5	27.0
August	......	......	......	28.9	23.0	27.5	30.0	25.5	27.8
September	......	......	......	26.0	20.0	23.5	27.8	17.8	24.7
October	18.3	14.4	[a] 16.5	22.0	14.5	18.9	23.9	15.5	[a] 20.5
November	16.0	10.5	13.3	18.9	11.7	15.0	......	......	......
December	13.3	6.0	10.5	17.0	9.5	12.0	......	......	......

Month.	1912			1913			1914		
	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.
January	......	......	......	......	......	......	15.0	5.0	9.4
February	......	......	......	......	......	......	14.0	3.0	9.4
March	......	......	......	......	......	......	16.0	3.0	9.8
April	......	......	......	......	......	......	23.0	12.0	16.8
May	......	......	......	......	......	......	26.0	18.0	22.0
June	29.5	20.0	25.4	28.0	17.0	21.0	30.0	22.0	26.1
July	30.0	26.0	28.0	30.0	26.0	27.8	30.0	25.0	28.0
August	28.9	23.9	27.0	30.0	26.0	27.8	......	......	......
September	28.9	20.5	26.3	28.0	22.0	24.6	......	......	......
October	24.4	16.0	20.0	25.0	14.0	19.9	......	......	......
November	20.0	7.8	13.6	16.0	9.0	13.6	......	......	......
December	16.7	7.0	11.5	14.0	7.0	10.5	......	......	......

[a] Record available for only part of month.

ARTIFICIAL KEY TO GENERA.

A. Color bluish green or blackish, sometimes grayish green or tinted with other colors; single celled or composed of rather short filaments; attached or floating; forming small tufts or rather gelatinous, feltlike masses over considerable areas of the substratum . . I. MYXOPHYCEÆ.

a. Plants unicellular, cells living singly or a few associated in small ill-defined families .... Chroococcus (p. 408).

aa. Plants multicellular, filamentous........ *b*.

b. Filaments tapering at apices into multicellular hairs........ Dichothrix (p. 416).

bb. Filaments not tapering to hairs at apices........ *c*.

c. Filaments unbranched........ *d*.

d. Filaments lacking sheath........ *e*.

e. Filaments, multicellular, elongated, straight or curved at the apices, not spirally twisted........ Oscillatoria (p. 410).

ee. Filaments unicellular, short, twisted into a regular, more or less lax spiral .... Spirulina (p. 411).

dd. Filaments with sheath........ *f*.

f. Filaments possessing heterocysts........ Microchæte (p. 414).

ff. Filaments lacking heterocysts........ *g*.

g. Filaments composed of several trichomes in each sheath........ Microcoleus (p. 413).

gg. Filaments composed of single trichomes in separate sheaths........ *h*.

h. Filaments about 1 mic. diameter........ Phormidium (p. 411).

hh. Filaments more than 1 mic. in diameter........ Lyngbya (p. 411).

cc. Filaments branched .... *i.*

i. Filaments lacking heterocysts .... Hydrocoleum (p. 413).

ii. Filaments possessing heterocysts .... Plectonema (p. 415).

AA. Color green; filamentous or forming tubes or sheets or complex structures of various shapes composed of closely interwoven filaments; usually attached, sometimes floating; some forms minute, living on or in shells or other algæ; some forms incrusted with lime .... II. CHLOROPHYCEÆ.

a. Frond flat, expanded .... *b.*

b. Outline irregular, indefinite, usually floating, attached when young .... Ulva (p. 420).

bb. Outline regular, definite; usually attached .... *Enteromorpha linza* (p. 420).

aa. Frond forming a hollow tube .... *c.*

c. Wall of tube composed of cells .... Enteromorpha (p. 418).

cc. Wall of tube not cellular, tube consisting of single unsegmented cavity of various complicated forms .... *d.*

d. Frond consisting of an upright stalk arising directly from the base, pinnately branched above .... Bryopsis (p. 431).

dd. Frond consisting of a creeping stem attached at intervals, from which arise erect branches of various forms .... Caulerpa (p. 434).

aaa. Frond filamentous .... *e.*

e. Frond microscopic, invisible to naked eye or visible only as a green stain on the substratum .... *f.*

f. Frond living in walls of other algæ .... Endoderma (p. 423).

ff. Frond living *on* surface of shells .... Ulvella (p. 423).

fff. Frond living *within* surface of shells .... Gomontia (p. 429).

ee. Frond easily visible to naked eye .... *g.*

g. Filaments unsegmented, loosely interwoven to form an irregular mat .... Derbesia (p. 430).

gg. Filaments segmented at regular intervals .... *h.*

h. Filaments unbranched .... Chætomorpha (p. 424).

hh. Filaments regularly branched; attached or floating .... Cladophora (p. 427).

hhh. Filaments usually with few irregular, rhizoidlike branches, sometimes unbranched, usually not attached .... Rhizoclonium (p. 427).

aaaa. Frond composed of branched filaments closely interwoven to form a complex structure .... *i.*

i. Frond fan shaped on an evident stalk, incrusted with lime .... Udotea (p. 433).

ii. Frond terete or somewhat flattened, dichotomously branched, spongy, not incrusted with lime .... Codium (p. 432).

AAA. Color brown, sometimes with greenish tinge; filamentous or forming complex structures of various shapes; usually attached; some forms minute, living on or in other algæ .... III. PHÆOPHYCEÆ.

a. Frond filamentous .... *b.*

b. Frond easily visible to naked eye .... Ectocarpus (p. 437).

bb. Frond microscopic, almost or quite invisible to naked eye .... *c.*

c. Frond growing *on* the surface of other algæ .... *d.*

d. Frond more or less spherical in outline, composed of decumbent radiating filaments united to form a basal layer from which arise erect filaments .... Myrionema (p. 445).

dd. Frond having no regular outline, composed of decumbent, irregularly dichotomous filaments .... Phæostroma (p. 442).

cc. Frond growing *within* the surface of other algæ .... *e.*

e. Frond forming its fruits above the surface in more or less spherical, dense clusters .... Elachistea (p. 444).

ee. Frond forming its fruits above the surface singly or in irregular, loose groups .... Streblonema (p. 440).

aa. Frond, small globose, hollow .... Leathesia (p. 447).

aaa. Frond mostly terete, with distinct central axis and lateral branches .... *f.*

f. Frond with many lateral branches leaflike, giving the appearance of stem and leaves, usually with berrylike floats .... Sargassum (p. 451).

ff. Frond with ultimate branchlets club shaped and terminated by brushlike tufts of hairs, no floats present........SPOROCHNUS (p. 448).

aaaa. Frond terete throughout, variously branched........*g*.

g. Frond forming a hollow tube, constricted and twisted at irregular intervals, about 2 mm. in diameter, dichotomously branched........ROSENVINGEA (p. 443).

gg. Frond not conspicuously tubular, about 1 mm. in diameter, irregularly branched, spongy texture........CASTAGNEA (p. 446).

ggg. Frond solid or nearly so, less than 1 mm. in diameter, dichotomously branched........STILOPHORA (p. 448).

aaaaa. Frond more or less flattened, simple or branched........*h*.

h. Frond consisting of one or more elongated, leaflike lobes........PETALONIA (p. 443).

hh. Frond fan shaped throughout or at least in the terminal segments........*i*.

i. Frond or segments bearing concentric zones parallel with the apical margins, apical margins inrolled........PADINA (p. 455).

ii. Frond or segments bearing radial markings running from the base to the apical margins, apical margins not inrolled........ZONARIA (p. 454).

hhh. Frond dichotomously branched........*j*.

j. Frond tough, leathery, usually with bladderlike floats at intervals in frond........FUCUS (p. 450).

jj. Frond membranaceous, no floats present........*k*.

k. Distinct midrib present........DICTYOPTERIS (p. 459).

kk. No midrib present........*l*.

l. Frond growing in length by group of initial cells, edges more or less serrate or dentate........SPATOGLOSSUM (p. 458).

ll. Frond growing in length by single apical cell, edges with occasional proliferations but not serrate or dentate........DICTYOTA (p. 460).

AAAA. Color various shades of red, pink, purple, sometimes blackish, yellowish, or green (if green, structure apparently cellular, not entirely composed of interwoven filaments), sometimes white from incrustations of lime; filamentous or forming sheets or complex structures of various shapes; some forms epiphytic, some minute, parasitic on other algæ; usually attached........IV. RHODOPHYCEÆ.

a. Frond not incrusted with lime........*b*.

b. Frond minute, parasitic, forming swollen knots on *Gymnogongrus griffithsiæ*.ACTINOCOCCUS (p. 477).

bb. Frond filamentous........*c*.

c. Filaments creeping, closely adherent, forming irregular patches........ERYTHROCLADIA (p. 466).

cc. Filaments more or less erect........*d*.

d. Filaments regularly dichotomous, tips usually incurved........CERAMIUM (p. 513).

dd. Filaments not regularly dichotomous........*e*.

e. Filaments consisting throughout, or for the most part, of a single row of cells; simple or branched........*f*.

f. Filaments sparse, scattered or few occurring in small tufts on other algæ; almost microscopic in size; slight branching by method known as "false branching"........GONIOTRICHUM (p. 465).

ff. Filaments composed of obovate or barrel-shaped cells........GRIFFITHSIA (p. 511).

fff. Filaments densely branched, forming erect, fairly conspicuous tufts on rocks or plants........CALLITHAMNION (p. 511).

ffff. Filaments growing in hydroids........*Acrochætium infestans* (p. 473).

fffff. Filaments forming more or less dense mats over other algæ........*g*.

g. Mat very fine, velvety, often inconspicuous except for the reddish tinge given the host; filaments minute........ACROCHÆTIUM (p. 469).

gg. Mat coarser, conspicuous........*h*.

h. Individual filaments easily discernible, rather coarse; mat dark red, rather loose........ERYTHROTRICHIA (p. 466).

hh. Individual filaments scarcely discernible, rather fine, velvety; mat bright red, dense........SPERMOTHAMNION (p. 510).

ee. Filaments at first consisting of single rows of cells, the upper cells of the filaments soon divided longitudinally, forming tubes; unbranched . . . BANGIA (p. 464).

eee. Filaments consisting throughout of several rows of cells. . . . . *i.*

i. Frond erect throughout, branching in all directions. . . . . POLYSIPHONIA (p. 502).

ii. Frond erect, arising from a creeping filament, branching alternately pinnate, distichous, giving a zigzag appearance. . . . . BOSTRYCHIA (p. 506).

iii. Frond creeping, forming a velvety mat with erect branches. . . . . HERPOSIPHONIA (p. 507).

bbb. Frond terete, at least for the most part. . . . . *j.*

j. Frond regularly dichotomous. . . . . *k.*

k. Frond small, about 3 cm. long and less than 1 mm. in diameter; horny, tough; dark greenish purple. . . . . GYMNOGONGRUS (p. 477).

kk. Frond large, 10 to 20 cm. long, 3 to 8 mm. in diameter; fleshy, soft; pink . . . . *Halymenia agardhii* (p. 517).

kkk. Frond large, 9 to 34 cm. long, 1 to 4 mm. wide, sometimes flattened, sometimes with pinnate branches in addition to dichotomies; cartilaginous, tough, coarse; red to purple and dark green. . . . . *Gracilaria multipartia* (p. 484).

kkkk. Frond large, 8 to 18 cm. long, 0.5 to 1 mm. in diameter; many pinnate branches in addition to dichotomies; ultimate branches beset with numerous fine hairs along their sides; red. . . . . *l.*

l. Hairs simple. . . . . SPYRIDIA (p. 512).

ll. Hairs branched. . . . . BRONGNIARTELLA (p. 505).

jj. Frond not regularly dichotomous. . . . . *m.*

m. Frond consisting of a solid stem and ultimate hollow, bladderlike branches . . . . *Chrysymenia uvaria* (p. 491).

mm. Frond hollow, tubular. . . . . *n.*

n. Frond large, up to 30 cm. long and 4 to 5 mm. in diameter; branches constricted at the bases. . . . . *Chrysymenia enteromorpha* (p. 490).

nn. Frond 1.5 to 6 cm. long, about 1 mm. in diameter; constricted at intervals, the tube containing transverse diaphragms at these constrictions. . CHAMPIA (p. 492).

nnn. Frond 1 to 3 cm. long, less than 1 mm. diameter; no transverse diaphragms; branches frequently arched and bearing branchlets principally along convex side; arched branches sometimes attached at their tips. . . . LOMENTARIA (p. 491).

mmm. Frond solid or nearly so . . . . *o.*

o. Frond small, 1 to 5 cm. long, 0.5 mm. or less diameter; upright branches arising from a creeping stem. . . . . GELIDIUM (p. 475).

oo. Frond larger than above. . . . . *p.*

p. Branches beset with numerous hairs along their sides; red. . . . . DASYA (p. 508).

pp. Ultimate branchlets constricted at the bases; red or reddish. . . . . . . CHONDRIA (p. 498).

ppp. Branches recurved at the apices or bearing short, pointed, spinelike branchlets; green. . . . . HYPNEA (p. 485).

pppp. Frond not distinguished by any of above characters. . . . . *q.*

q. Branches arising on stem in two rows, main axis somewhat flattened. . . . . *r.*

r. Texture somewhat gelatinous; branching pinnate throughout; cystocarps internal. . . . . RHABDONIA (p. 480).

rr. Texture somewhat cartilaginous; branching partly dichotomous; cystocarps external, conspicuous. *Gracilaria multipartita* (p. 484).

qq. Branches arising on all sides or at least not in two rows, main axis not flattened. . . . . *s.*

s. Cystocarps internal. . . . . *t.*

t. Texture rather gelatinous, soft. . . . . AGARDHIELLA (p. 478).

tt. Texture rather cartilaginous, rigid. . . . . EUCHEUMA (p. 481).

ss. Cystocarps external. . . . . *u.*

u. Texture fleshy-cartilaginous; frond slender, usually not more than 1 mm. in diameter, beset with many short fine branchlets, smaller branches long, slender . . . . *Gracilaria confervoides* (p. 483).

uu. Texture rather cartilaginous; frond coarse, 1 to 1.5 mm. in diameter, sparingly branched, small branches few, usually coarse .... *Gracilaria multipartita* (p. 484).

uuu. Texture cartilaginous, wiry; frond coarse, densely branched, branches interwoven, beset with many short, coarse, blunt branchlets .... LAURENCIA (p. 497).

bbbb. Frond flattened .... *v*.

v. Frond 1 to 25 mm. wide in widest part .... *w*.

w. Frond regularly dichotomous .... *x*.

x. Frond 4 to 12 mm. wide in widest part, 2 to 8 cm. long, membranaceous, fleshy, rather thick, edges smooth; red or pink .... RHODYMENIA (p. 487).

xx. Frond 12 to 25 mm. wide in widest part, 3 to 10 cm. long, fleshy, rather coarse, edges ruffled; purple .... CRYPTONEMIA (p. 521).

xxx. Frond 10 to 25 mm. wide in widest part, 6 to 20 cm. long, thin membranaceous, veined, edges wavy, slightly proliferous; bright pink .... NITOPHYLLUM (p. 494).

ww. Frond pinnately or irregularly branched .... *y*.

y. Frond not more than 1 mm. wide, fleshy, rather densely pinnately or irregularly branched; dark purple .... *Grateloupia filicina* (p. 521).

yy. Frond 6 to 18 mm. wide in widest part, fleshy, main axis conspicuously larger than branches, densely decompound distichously branched, branches sometimes dichotomous, all branches flat, numerous branchlets frequently arising from the flat surfaces; purplish green .... *Grateloupia gibbesii* (p. 521).

yyy. Frond 9 to 15 mm. wide in widest part, gelatinous, main axis conspicuously larger than branches, sparingly distichously branched, ultimate branches rounded; pink .... *Halymenia floresia* (p. 518).

vv. Frond 40 to 130 mm. wide in widest part .... *z*.

z. Frond very thin membranaceous, delicate .... *a′*.

a′. Frond pink, simple or sparingly branched, bearing a conspicuous midrib and sometimes fine pinnate veins; fruit appearing as conspicuous dots on surface .... GRINNELLIA (p. 495).

aa′. Frond purple, simple or irregularly divided into lobes, structure uniform; fruit not visible to naked eye .... PORPHYRA (p. 464).

zz. Frond firm, membranaceous or fleshy .... *b′*.

b′. Frond dichotomously branched .... AGARDHINULA (p. 488).

bb′. Frond simple or lobate, not dichotomous .... *c′*.

c′. Frond fleshy-cartilaginous, coarse, simple, or irregularly divided into lobes not reaching to the base, sometimes proliferous from the margins, stem inconspicuous; cystocarpic fruit borne in conspicuous, short protuberances arising from edges and surface; usually dark red, sometimes yellowish .... MERISTOTHECA (p. 479).

cc′. Frond firm membranaceous, thin, usually divided into several more or less regular ovate or elliptical lobes arising from the base on distinct stalks; fruit in inconspicuous dots on surface; purplish pink .... *Halymenia floridana* (p. 519).

ccc′. Frond gelatinous-fleshy, light pink, sometimes with yellowish tinge .... *d′*.

d′. Frond simple or divided into several lobes borne on distinct stalks; frond or lobes ovate .... *Halymenia gelinaria* (p. 518).

dd′. Frond simple or irregularly divided into lobes; frond or lobes lanceolate .... *Chrysymenia agardhii* (p. 490).

aa. Frond incrusted with lime .... *e′*.

e′. Frond erect, filiform, jointed .... *f′*.

f′. Conceptacles immersed, scattered over the segments .... AMPHIROA (p. 526).

ff′. Conceptacles immersed in the apices of terminal segments, opening by terminal pores, the fertile segments sometimes bearing hornlike lateral branches. CORALLINA (p. 527).

ee'. Frond horizontally expanded forming small, more or less definite, disk-shaped spots on the substratum..*g'*.

g'. Frond thin, consisting of a single uniform layer; larger cells present among ordinary cells; conceptacles small..MELOBESIA (p. 523).

gg'. Frond fairly thick, differentiated into a thin basal layer and a thicker upper one; cells of fairly uniform size; conceptacles large............DERMATOLITHON (p. 524).

eee'. Frond forming indefinite expansions over the substratum...................................*h'*.

h'. Tetrasporangial conceptacles opening by a separate pore for each sporangium ....LITHOTHAMNIUM (p. 524).

hh'. Tetrasporangial conceptacle opening by a single apical pore........LITHOPHYLLUM (p. 525).

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GLOSSARY.

Acuminate, tapering gradually to a point.

Acute, having a distinct point, but not greatly elongated.

Adherent, attached more or less closely.

Adnate, attached by growth, grown together.

Æruginous, the blue-green color of verdigris.

Aggregated, massed together.

Akinete, a nonsexual reproductive cell formed by the massing of the contents of a vegetative cell, the wall of the mother cell thickening and functioning as the wall of the akinete.

Alternate, placed on opposite sides of a stem at different levels.

Anastomose, to run together and fuse into more or less of a network.

Anastomosis, the union of filaments or tubes with each other.

Ancipitate, two edged, flattened or compressed.

Antheridium (pl. *antheridia*), the organ forming male cells.

Anticlinal, perpendicular to the surface.

Apical, at or near the apex or tip.

Apiculum, a short, sharp point.

Aplanospore, a nonsexual reproductive cell formed by the massing of the contents of a vegetative cell and the formation about this of a new cell wall.

Approximate, situated close together, but not united.

Arcuate, curved like a bow.

Articulation, the joint of a more or less segmented structure.

Assimilating filaments, filaments borne on the surface, containing chlorophyll (and, usually, other pigments), and carrying on the process of photosynthesis, used especially in the Phæophyceæ to distinguish from superficial, colorless filaments.

Attenuate, attenuated, narrow and tapering.

Austral, southern, usually referring to the Southern Hemisphere.

Auxiliary cell, a cell in the Florideæ receiving a nucleus from the fertilized egg and, as a result of this, forming reproductive spores.

Axial, relating to the axis.

Axil, the distal (more apical) angle between the axis and an organ arising from it.

Axillary, growing in an axil.

Axis, the line running the length of a plant around which the branches are borne.

Biciliate, possessing two cilia.

Bipartite, divided into two parts.

Boreal, northern, usually referring to the Northern Hemisphere.

Brood bud, a specialized multicellular structure formed from a vegetative portion of a plant and serving for propagation.

Cæspitose, growing in tufts.

Calcified, containing a deposit of lime.

Callus, an abnormally thickened part, usually as a result of a wound.

Calyptra, a cap, used for the thickening of the outer wall of the apical cell of some Myxophyceæ.

Calyptrate, bearing a calyptra.

Capillary, slender, like a hair.

Capitate, used in the Myxophyceæ for the termination of a filament in a more or less globose head.

Carpogenic branch, a short, specialized, usually 3 or 4 celled, filamentous branch, occurring in the Florideæ, often immersed in the thallus, and bearing at its apex the female organ, carpogonium.

Carpogonium, the female organ of the Rhodophyceæ, consisting, in the Florideæ, of a swollen basal portion within which the egg is borne, and a hairlike, apical prolongation, the trichogyne.

Carpospore, a spore formed in the Rhodophyceæ as a result of the fertilization of the carpogonium.

Carpostome, the opening in the sterile jacket inclosing the carpospores of many Florideæ, through which the carpospores are shed.

Cartilaginous, hard and tough, having the texture of cartilage.

Caulescent, possessing a stalk.

Cellulose, a carbohydrate forming the principal constituent of young and unaltered cell walls; e. g., in the cotton of commerce.

Chlorophyll, the green coloring matter of plants.

Chromatophore, a body within a plant cell specialized to contain pigment.

Cilium (pl., *cilia*), a short, whiplike projection of a motile cell by means of which the cell propels itself; a minute outgrowth from a plant.

Clavate, club shaped, thickened toward the apex.

Claviform, club shaped.

cm., abbreviation for centimeter, about two-fifths of an inch.

Coalescent, becoming united by growth.

Compacted, closely packed or pressed together.

Conceptacle, a superficial cavity opening to the surface, within which reproductive organs are developed.

Confervoid, composed of unbranched filaments, threadlike.

Confluent, blended into one.

Conglobate, collected into a ball.

Conic, *conical*, cone shaped.

Constricted, narrowed, contracted.

Copulation, the union of sexual cells or organs.

Coriaceous, leathery.

Cortex, the tissue of a more or less solid alga lying beneath the epidermis, between this and the central region, medulla; when no epidermis is present, the outer region of the thallus surrounding the medulla.

Cortical, belonging to or occurring in the cortex.

Corticated, provided with a cortex.

Corymb, a flat-topped or convex cluster with the younger parts toward the middle.

Corymbose, occurring in corymbs.

Crateriform, cup shaped.

Crenate, scalloped, provided with rounded, wavy teeth or notches.

Cruciate, a method of division of a tetrasporangium by walls at right angles to each other, all of the four resulting tetraspores being visible in one plane, grouped around a common center.

Crustaceous, the thallus consisting of a relatively thin layer closely adherent to the substratum and of brittle texture.

Cryptostoma (pl., *crypstostomata*), a small cavity sunk in the thallus and bearing only hairs (paraphyses), found in the Fucaceæ.

Cuneate, wedge shaped.

Cuticle, the structureless layer bounding the outer surface of many plants.

Cyathiform, shaped like a wineglass.

Cylindric, elongated with a circular cross section.

Cymose, occurring in a more or less broad, flat-topped cluster, with the younger parts toward the periphery.

Cystocarp, a fruit produced as a result of the fertilization of the egg in the carpogonium, including the mass of carpospores, the accessory structures, and the inclosing, cellular, protective structures, found in many of the Florideæ.

Cystocarpic, bearing cystocarps, used to designate the female plant.

Decompound, divided several times.

Decumbent, reclining, but with the apex ascending.

Dentate, provided with sharp, toothlike structures.

Dichotomous, a method of branching by forking into two parts of approximately equal size.

Dichotomy, a forking into two parts.

Diffluent, becoming separate.

Diœcious, bearing male and female organs on separate plants.

Discoid, disklike, having a flat, rounded shape.

Discrete, separate, not coalescent.

Disporangium (pl., *disporangia*), a sporangium whose contents are divided into two spores.

Dissepiment, a partition.

Distichous, having the parts borne in two vertical rows, usually from the edges of a more or less flattened structure.

Divaricate, extremely spreading.

dm., abbreviation for decimeter, about 4 inches.

Dorsal, referring to the upper, or back, surface of a dorsiventral structure.

Dorsiventral, having unlike surfaces corresponding to back and front or upper and lower.

Ectosarc, the horny outer covering of hydroids.

Ellipsoid, having an elliptical shape.

Elliptical, oblong with regularly rounded ends.

Endochrome, the coloring matter contained within cells.

Endophytic, growing within the tissue of another plant.

Epidermal, belonging to the epidermis.

Epidermis, a definite, differentiated layer of cells bounding the outer surface of a plant.

Epiphytic, growing on another plant, using the host only for attachment, and not obtaining material from it.

Eroso-denticulate, having minute, irregular, marginal teeth, the margin being so irregular as to appear gnawed or bitten.

Excentric, out of the center, one-sided.

Exserted, protruding beyond the surface.

False branching, a type of branching in which a cell in the midst of a filament elongates and, pushing to one side, continues the growth in a new direction, found principally in the Myxophyceæ.

Farinaceous, rough and scaly in appearance.

Fascicle, a close cluster of stems or branches.

Fascicled, *fasciculate*, borne in a fasciclelike manner.

Fastigiate, the occurrence of stems or branches in erect, parallel clusters.

Fenestrate, pierced with holes.

Filamentous, threadlike.

Filiform, long, with a circular cross section.

Fistulose, hollow throughout its length.

Flabellate, fan shaped.

Flabellum, a fan-shaped structure.

Flaccid, limp, not rigid.

Flagelliform, like the lash of a whip.

Flexuous, flexible, easily bent; bent alternately in different directions.

Floccose, occurring in small, soft tufts or masses.

Foliaceous, flat and expanded like a leaf.

Forcipate, forked, with the apices approaching each other, like a pair of forceps.

Fragmentation, a breaking into pieces.

Fructification, fruiting, the bearing of organs of propagation or reproduction.

Fucoxanthin, a brown pigment found in some of the Phæophyceæ.

Furcate, forked, with terminal lobes like prongs.

Fusiform, spindle shaped, thick in the middle and tapering toward each end.

Fusoid, somewhat fusiform.

Gametangium (pl., *gametangia*), an organ bearing gametes.

Gamete, a sexual cell.

Ganglion (pl., *ganglia*), an enlargement caused by the fusion of separate filaments, or an enlarged portion of a filamentous structure from which smaller filaments radiate.

Glaucous, covered with a bloom, as on the fruit of the plum.

Globose, nearly spherical.

Glomerulus (pl., *glomeruli*), a roundish cluster of organs closely grouped into a common structure.

Gonidangium (pl., *gonidangia*), a specialized cell bearing gonidia.

Gonidium (pl., *gonidia*), a cell formed nonsexually and slightly specialized for propagation.

Gonimoblast, a cluster of filaments formed as a result of the fertilization of the egg in a carpogonium, some of whose cells become changed into carpospores, found in the Florideæ.

Gonimolobe, one of the lobes into which the gonimoblast may be divided.

Hermaphroditic, bearing male and female organs on the same individual.

Heterocyst, a more or less specialized cell which differs in appearance from the other cells, used in the Myxophyceæ for large cells occurring within the filaments and serving to break these apart; used in Melobesia for isolated large cells of unknown function.

Heterogametes, sexual cells in which the members of the fusing pairs differ from each other.

Heteromorphous, having a different shape.

Hormogonium (pl., *hormogonia*), a multicellular portion of a filament, becoming separate and serving for propagation, found in the Myxophyceæ.

Hyaline, colorless or translucent.

Hydranth, one of the individuals in a hydroid colony.

Hymenium, a network of more or less coalescent filaments forming a surface on which fruits are borne, a fruiting surface.

Hypothallium, the ventral (lower) portion of a flat thallus that is differentiated into two regions.

Incised, cut sharply into the margin.

Indusium, a sterile outgrowth of a thallus or structure covering fruiting organs.

Integument, the outer covering of an organ or body.

Intercalary, situated at some place between the apex and the base.

Intercellular, between the cells.

Internode, the space between two nodes.

Interpilar, between the rows of hairs.

Intricate, entangled.

Isogametes, sexual cells in which the members of the fusing pairs are similar.

Lacerate, appearing torn, or irregularly cleft.

Laciniate, cut into narrow lobes.

Lamellose, made up of thin plates joined into a common structure.

Lamina, the flattened portion of a leaflike structure.

Lanceolate, narrow, and tapering toward each end.

Linear, narrow, several times longer than wide.

Lobate, divided into or bearing lobes.

Lobe, a division of an organ or thallus.

Medulla, the central tissue of a more or less solid alga.

Medullary, situated in or belonging to the medulla.

Mic., abbreviation for micron, the unit of microscopic measure, the one-thousandth part of a millimeter.

Midrib, a thickened portion running midway along a flattened thallus.

mm., abbreviation for millimeter, about one twenty-fifth of an inch.

Moniliform, like a string of beads.

Monociliate, having a single cilium.

Monœcious, bearing male and female organs on the same plant.

Monopodial, a method of branching in which there is a distinct main stem running to the tip and lateral branches of smaller size than the central axis.

Monosiphonous, consisting of a single row of cells.

Monosporangium, a sporangium whose entire contents are formed into a single spore.

Monospore, a spore formed in a monosporangium.

Monostromatic, consisting of a single layer of cells.

Moriform, shaped like a mulberry.

Mucronate, possessing a short, straight point.

Multicellular, consisting of more than one cell.

Multifid, divided many times into lobes or segments.

Multinucleate, containing more than one nucleus.

Nematheciform, shaped like a nemathecium.

Nemathecium (pl. *nemathecia*) a wartlike elevation of the surface containing organs of reproduction.

Node, a joint in a distinctly segmented stem.

Nodule, a small knot, or thickened, dense structure.

Nucleus, a differentiated portion of the living material contained, usually, near the center of each cell; the central mass in the sexually formed fruit of some Florideæ.

Obconi-obovoid, obovate, but more narrowed at the narrower (basal) end.

Obdeltoid, shaped like the Greek capital letter delta, but reversed, with the narrower part toward the base.

Oblong, longer than broad, with nearly parallel sides.

Obovate, reversed ovate, with narrower end toward the base.

Obtuse, blunt or rounded at the end.

Oogonium (pl. *oogonia*), a single-celled female organ bearing one or more eggs.

Orbicular, flat with a circular outline.

Ovate, *ovoid*, egg shaped.

Palmate, divided into lobes arising from a common base, like the fingers from a hand.

Palmatifid, divided in a palmate manner almost to the base.

Paniculate, having the branches or parts arranged in a loose cluster.

Papilla, a small, short, superficial outgrowth.

Papillate, bearing papillæ.

Paraphysis (pl. *paraphyses*), a sterile filament projecting, usually, from the surface of many algæ, usually borne in clusters, frequently with the fruiting organs.

Parasitic, living on or in another plant or animal and obtaining nourishment from it.

Parenchymatous, consisting of loose tissue, composed of thin-walled cells of fairly uniform diameter in every direction, and often with conspicuous intercellular spaces.

Parietal, situated toward the wall, away from the center.

Parthenogenetically, applied to a method of development in which an egg develops without fertilization.

Patent, spreading.

Pectinate, pinnately divided into narrow segments or branches set close together like the teeth of a comb.

Pedicel, a short stalk bearing a specialized organ.

Pedicellate, borne on a pedicel.

Peduncle, a stalk bearing an organ or a group of organs, larger than a pedicel.

Penicillate, shaped like a pencil.

Perforate, pierced through, forming a hole.

Pericarp, the differentiated, sterile, cellular, protective structure inclosing the carpospores and accessory structures in many Florideæ.

Pericentral, applied to structures grouped around a common center or axis.

Peripheral, toward the circumference.

Perithallium, the dorsal (upper) portion of a flat thallus which is differentiated into two regions.

Petiole, the stem of a leaflike structure.

Phycoerythrin, a red pigment occurring in the Rhodophyceæ.

Piliferous, bearing hairs.

Pinna (pl. *pinnæ*), one of the divisions of a pinnately divided structure.

Pinnate, having branches or parts on opposite sides of a common stem or axis, as in a feather.

Pinnulate, applied to a structure which has pinnæ pinnately divided, twice pinnate.

Pinnule, one of the secondary divisions of a pinnulately divided structure.

Placenta, a more or less conspicuous structure serving as the place of origin and attachment for the gonimoblasts in the sporocarp of many Florideæ.

Plumose, featherlike or plumelike.

Plurilocular, a term used for the reproductive organs of many Phæophyceæ which are divided by walls into numerous compartments, producing a single motile reproductive cell in each compartment.

Polychotomous, a method of branching in which the thallus is divided into many parts of more or less equal size.

Polygonal, having many angles and many sides.

Polysiphonous, consisting of several coherent longitudinal rows of cells.

Polyspores, many spores borne in one sporangium.

Procarp, the complex female organ of many Florideæ, consisting of the carpogonium, one or more auxiliary cells, and other accessory cells.

Proliferation, an outgrowth.

Proliferous, bearing outgrowths.

Propagulum (pl. *propagula*), a many-celled body, formed from a vegetative portion of a plant, and specialized for propagation.

Pseudo-, used as a prefix to denote having the appearance of possessing a quality but not possessing it.

Pulvinate, cushion shaped.

Pyramidal, pyramid shaped.

Pyrenoid, a small, definite, rounded, colorless body occurring in a chloroplast and serving as a center of starch accumulation.

Pyriform, pear shaped.

Quadrate, four sided, square.

Racemose, arranged in a cluster of branches along a central axis, the branches becoming of approximately equal lengths and having the older ones below.

Radial, radiating, as from a center.

Ramulus (pl., *ramuli*), a small branch.

Receptacle, the enlarged fruiting portion of the plant, bearing the sunken cavities (conceptacles), in the Fucaceæ.

Reticulate, forming a network.

Rhizoid, a cellular filamentous outgrowth serving as an organ of attachment.

Rhizoidal, pertaining to rhizoids.

Rhizome, a creeping portion of a thallus resembling a horizontal stem and giving off upright stemlike or leaflike branches.

Rimose, having cracks in the surface, as in the old bark of trees.

Rotund, rounded in outline, but a little inclined toward oblong.

Scutellate, shaped like a small platter.

Secund, bearing branches or organs on only one side of an axis.

Septate, bearing septa.

Septum (pl., *septa*), a partition.

Seriate, arranged in series or rows.

Serrate, bearing numerous short, sharp, marginal teeth, like those of a saw.

Serration, the bearing of serrate teeth.

Sessile, borne directly on the axis, not on a stalk.

Setaceous, very slender and rigid, bristlelike.

Silique, the peculiar pod of the mustard family.

Sinus, the more or less acute angle formed by the division of a thallus into approximately equal parts.

Sorus (pl., *sori*), a definite cluster of reproductive organs.

Spatulate, oblong, with the basal end attenuated, like a spatula.

Spermatangium (pl., *spermatangia*), a more or less specialized organ bearing male cells.

Spermatium (pl., *spermatia*), a nonmotile male cell, occurring in the Rhodophyceæ.

Sporangiferous, bearing sporangia.

Sporangium (pl., *sporangia*), a specialized organ bearing spores formed nonsexually.

Spore, a cell specialized for propagation and capable, without fusion with any other cell, of growing into a new plant.

Sporocarp, a fruit produced as a result of the fertilization of the egg in the carpogonium, including the carpospores and the accessory structures, occurring in the Florideæ.

Stellate, star shaped.

Stichidium (pl., *stichidia*), a specialized branch bearing tetrasporangia, occurring in a few Florideæ.

Stipe, the narrow, stemlike stalk by which a flattened thallus is attached.

Stipitate, possessing a stipe.

Stolon, a horizontal, stemlike portion which, attaching itself and becoming separate from the parent, forms a new plant.

Sub-, used as a prefix to denote somewhat, to a limited degree, as subacute; used as a prefix to denote under, as subcortex.

Substratum, the underlying substance on which a plant is growing.

Subulate, *subuliform*, awl shaped, long, slender, and pointed.

Sympodial, having an arrangement where each branch forms a part of the main axis, the resulting axis thus being formed partly from the branches, but resembling a simple axis.

Synonym, an incorrect name used for a species which has a correct name.

Taxonomic, referring to the classification of plants according to their relationships.

Terete, cylindrical and usually tapering, circular in cross section.

Tetrahedral, four sided, used especially with reference to apical cells, and sometimes to tetrasporangia which are triangularly divided.

Tetrasproangium (pl., *tetrasporangia*), a sporangium whose contents are divided into four spores, occurring in the Florideæ and the Dictyotaceæ.

Tetraspore, one of the four spores formed in a tetrasporangium.

Tetrasporic, bearing tetraspores, frequently used with the same meaning as asexual.

Thallus, a plant body not distinctly differentiated into stem and leaf.

Tortuous, bent or twisted in different directions.

Torulose, cylindrical, with swollen portions at intervals, somewhat moniliform.

Triangular, a method of division of a tetrasporangium by four walls formed in different planes and meeting at the center, three of the resulting tetraspores usually being visible on a single surface, each appearing triangular in shape.

Trichoblast, a filamentous, lateral outgrowth consisting of a single row of cells, usually much branched, borne on the surface of a thallus.

Trichogyne, the slender prolongation of the female organ (carpogonium) of the Florideæ with which the male cell fuses as the beginning of fertilization.

Trichome, any hairlike outgrowth from the surface.

Trichothallic, a method of growth in a thallus bearing apical hairs by cell divisions at the bases of the hairs between these and the wider part of the thallus.

Trichotomous, a method of branching by forking into three approximately equal parts.

Truncate, appearing as if cut off at the end.

Turgid, distended by the pressure due to the cell contents.

Undulate, wavy.

Uniaxial, having a single primary axis.

Unilateral, one sided, borne on or turned to one side.

Unilocular, a term used for the sporangia of many Phæophyceæ which are not divided into separate compartments, but produce numerous motile spores in the single cavity of the sporangium.

Unisexual, bearing the organs of only one sex on a single individual.

Urceolate, pitcherlike.

Vacuole, a cavity in the living material of cells, containing a clear, watery solution, the cell sap.

Ventral, referring to the lower, or front, surface of a dorsiventral structure.

Verrucose, appearing as if having warts, warty.

Verticillate, arranged in a whorl of similar parts around an axis.

Vesicle, a small, bladderlike structure or cavity.

Vesicular, possessing vesicles.

Virgate, long, slender, and unbranched, wand shaped.

Zonate, a method of division of a tetrasporangium by three walls in the same plane, all four resulting tetraspores being visible from the surface, lying in a single row.

Zonation, the superficial marking of a thallus by concentric lines.

Zoospore, a motile spore.

Zygote, the cell formed by the fusion of two sexual cells.

EXPLANATION OF PLATES.

Plate LXXXIV: 1. *Cladophora crystallina*×1/1. 2. *Udotea cyathiformis*×1 1/10. 3. *Udotea cyathiformis*×4/5 circ. 4. *Bryopsis plumosa*×60/67.

Plate LXXXV: 1. *Codium tomentosum*×1/6. 2. *Codium decorticatum*×8/27 circ.

Plate LXXXVI: 1. *Petalonia fascia*×37/50 circ. 2. *Rosenvingea orientalis*×3/8 circ.

Plate LXXXVII: 1. *Castagnea zosteræ*×71/100. 2. *Stilophora rhizodes*×13/35 circ.

Plate LXXXVIII: 1 and 2. *Leathesia difformis*×1/1 circ. 3. *Sporochnus pedunculatus*×1/1.

Plate LXXXIX: *Fucus vesiculosus*×2/5.

Plate XC: 1. *Sargassum natans*×1/4 circ. 2. *Sargassum filipendula*×1/3 circ.

Plate XCI: 1. *Zonaria flava*, bearing *Spermothamnion investiens*×2/3 circ. 2. *Zonaria variegata*×5/8 circ.

Plate XCII: 1. *Padina vickersiæ* (type)×1/4 circ. 2. *Padina vickersiæ*×1/2.

Plate XCIII: 1. *Spatoglossum schrœderi*×1/3 circ. 2. *Dictyopteris polypodiodes*×1/3 circ. 3. *Dictyopteris serrata*×2/5 circ.

Plate XCIV: 1. *Dictyota dichotoma*, usual form from Fort Macon jetty, *a*, male; *b*, female×2/5. 2. *a* and *b*, *Spatoglossum schrœderi*×38/87; *c* and *d*, *Dictyota dichotoma*, narrow form from coral reef×38/87. 3. *Dictyota dichotoma*, male, bearing proliferations from apices×1/3.

Plate XCV: 1. *Gelidium coerulescens*×3/5 circ. 2. *Gelidium crinale*×1 3/5. 3. *Gymnogongrus griffithsiæ*×1/2 circ.

Plate XCVI: 1. *Agardhiella tenera*, usual form×15/29. 2. *Agardhiella tenera*, slender form from coral reef×1/3 circ.

Plate XCVII: 1. *Meristotheca duchassaingii; a*, cystocarpic; *b*, tetrasporic, bearing *Streblonema invisibile*×11/28 circ. 2. *Meristotheca duchassingii*×11/36 circ.

Plate XCVIII: 1. *Rhabdonia ramosissima*×9/16 circ. 2. *Eucheuma gelidium*×2/7 circ.

Plate XCIX: 1. *Gracilaria confervoides*, cystocarpic×2/5 circ. 2. *Gracilaria multipartita*, from harbor; *a* and *b*, sterile; *c*, cystocarpic×16/35 circ.

Plate C: 1. *Hypnea musciformis*, type 1, tetrasporic×2/5 circ. 2. *Hypnea musciformis*, type 2, cystocarpic×2/5 circ.

Plate CI: 1. *Hypnea musciformis*, type 3, cystocarpic×9/26. 2. *Hypnea musciformis*, winter condition ×4/5. 3. *Rhodymenia palmetta*×25/39. 4. *Rhodymenia palmetta*×9/28 circ.

Plate CII: 1. *Agardhinula browneæ*, cystocarpic×7/12. 2. *Chrysymenia agardhii*×1/2.

Plate CIII: 1. *Chrysymenia enteromorpha*, from Bogue Beach×1/2 circ. 2. *Chrysymenia enteromorpha* from coral reef×2/5 circ.

Plate CIV: 1. *Chrysymenia uvaria*×7/12 circ. 2. *Lomentaria uncinata*×3/4. 3. *Lomentaria rosea*×1/3 circ. 4. *Champia parvula*×6/7.

Plate CV: *Nitophyllum medium;* 1. Sterile, densely branched×3/7 circ. 2. Type, veins evident, tetrasporangial sori in rather irregular lines×1/3 circ. 3. Veins conspicuous, tetrasporangial sori in unusually regular lines or very irregular×3/7 circ.

Plate CVI: 1. *Grinnellia americana*, tetrasporic×3/7 circ. 2. *Laurencia tuberculosa* var. *gemmifera*×3/5 circ.

Plate CVII: 1. *Chondria littoralis*×1/3 circ. 2. *Chondria dasyphylla*, winter condition×1/1. 3. *Chondria tenuissima* var. *baileyana*×5/8. 4. *Chondria dasyphylla*×3/8 circ.

Plate CVIII: 1. *Chondria sedifolia*, cystocarpic×3/5 circ. 2. *Chondria sedifolia*, tetrasporic×9/20 circ. 3. *Polysiphonia havanensis*×7/15. 4. *a* and *b*, *Polysiphonia denudata; c*, *Polysiphonia harveyi*×10/11.

Plate CIX: 1. *Polysiphonia denudata*×4/11 circ. 2. *Polysiphonia denudata*×14/17. 3. *Polysiphonia nigrescens*×15/16. 4. *Brongniartella mucronata*×19/30.

Plate CX: 1. *Herposiphonia tenella* on *Gracilaria multipartita*×1/2. 2. *Dasya pedicellata*×29/56.

Plate CXI: 1. *Spyridia filamentosa*×10/21. 2. *Ceramium rubrum*×1/2 circ. 3. *Ceramium strictum*×7/15.

PLATE CXII: 1. *Halymenia decipiens* ×1/3 circ. 2. *Halymenia floresia* ×1/2 circ. 3. *Halymenia gelinaria* ×3/5. 4. *a*, *Halymenia gelinaria* ×3/7 circ.; *b*, *Halymenia floridana* ×3/7 circ.; *c*, *Amphiroa fragilissima* ×3/7 circ. 5. Undetermined species, No. 1×9/16.

PLATE CXIII: 1. *Grateloupia filicina* ×5/14 circ. 2. *Grateloupia gibbesii* ×1/3 circ. 3. *Cryptonemia crenulata* ×6/11. 4 and 5. *Corallina cubensis*. 4. ×1/1. 5. ×1 1/3.

PLATE CXIV: 1, 2, and 3. *Padina vickersiæ;* 1, cross section of thallus and oogonial sorus, oogonia almost mature; 2, cross section of thallus and tetrasporangial sorus, showing undivided tetrasporangia; 3, cross section of thallus and antheridial sorus, antheridia almost mature×272. 4. *Nitophyllum medium*, type, cross section of thallus showing, below, edge of soral thickening composed of three cell layers, three veins shown cut across; the central one has adjoining portion of thallus three cells deep with irregular thickenings on walls×272. 5. *Nitophyllum medium*, cross section of tetrasporangial sorus, showing soral thickening, undivided tetrasporangia, and veins×272. 6. *Corallina capillacea* ×50.

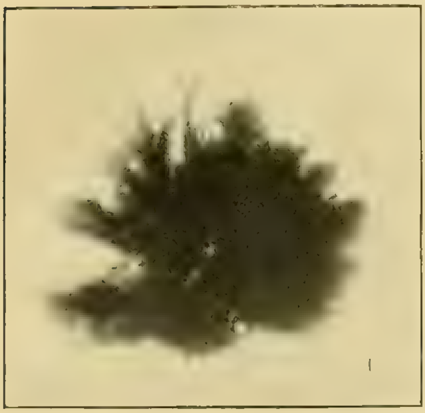
PLATE CXV: 1 to 9. *Phæostroma pusillum;* 1, margin of thallus, showing separate creeping filaments, plurilocular sporangia, hair, etc. ×245; 2, enlarged detail, showing immature plurilocular sporangium, chromatophores, etc. ×1040; 3, mature plurilocular sporangium in obliquely longitudinal view×670; 4, mature plurilocular sporangium viewed from above (end view)×670; 5, margin of thallus (more compact than that shown in fig. 1), with unilocular sporangia, a sorus at *a* and the beginning of a sorus at *b*×245; 6, enlarged detail of thallus, showing chromatophores and unilocular sporangia as seen from above×1040; 7, young unilocular sporangium viewed from above×1040; 8, the beginning of a sorus viewed from above×1040; 9, a mature sorus of unilocular sporangia viewed from above×1040. 10 to 16. *Derbesia turbinata;* 10, apex of thallus showing a young lateral branch×81; 11, lateral or unequal dichotomous branching×81; 12, dichotomous branching×81; 13 to 16, usual forms of sporangia×162, 13 and 15 showing pedicel cells. Drawings by M. A. Howe, from Howe and Hoyt, 1916.

PLATE CXVI: 1. *Erythrocladia recondita* on *Dictyota dichotoma*, photograph made after staining with iodine, showing habit of plant and sporocarps (the larger darker cells)×160. 2. *Erythrocladia vagabunda* on *Dictyota dichotoma*, photograph made after staining with iodine, showing habit of plant and sporocarps (some of the larger cells)×160, a small colony of *E. recondita* with smaller darker cells shown near *B* at the lower right-hand corner. From Howe and Hoyt, 1916.

PLATE CXVII: 1 to 5. *Erythrocladia recondita;* 1, portion of thallus near margin viewed from above, showing outlines of protoplasts and of pyrenoids with outlines of the cortical cells of its host×670; 2 and 3, portions of cross sections of endophyte and its host, showing the immersed vegetative cells and the more or less exserted spermatia (spm.)×670; 4, portion of a cross section showing a carpogonium with exserted trichogyne×670; 5, portion of pseudoparenchymatous thallus viewed from above, showing protoplasts of vegetative cells, spermatia (spm), carpogonium (cpg), and sporocarps (spcp)×670. 6 to 11. *Erythrocladia vagabunda;* 6, portion of thallus viewed from above, showing outlines of protoplasts and of pyrenoids with outlines of the cortical cells of its host×415; 7, portion of thallus showing three vegetative cells, six sporocarps (spcp), and five cavities from which carpospores have been discharged×670; 8 to 9, portions of thalli showing vegetative cells and sporocarps (spcp)×415; 10, a single carpospore lying on the surface of its host, in the outer walls of which it is already partially immersed×670; 11, a young filament (four-celled stage) viewed from above×415. 12 to 17. *Microchæte nana;* 12, a young filament, prostrate, but beginning to turn upward at apex, thickness of sheath slightly exaggerated×670; 13, older and normally curved filament showing two basal heterocysts (not common), thickness of sheath slightly exaggerated×670; 14, an unusually straight, apparently mature filament×245; 15, filament showing curve of a frequent form×245; 16 and 17, apex and base of filament shown in fig. 15 ×670. Drawings by M. A. Howe, from Howe and Hoyt, 1916.

PLATE CXVIII: *Acrochætium infestans;* 1. Filaments of the usual form in the wall of a hydroid, with two exserted filaments, only the protoplasts being shown in the immersed portions, since the cell walls are almost invisible×670. 2. An exserted sporangium sessile on an interior filament×670. 3. An exserted filament of three cells, one being a sporangium and another probably an immature sporangium×670. 4. An exterior filament with short branches, short hairs, and a single lateral sporangium×670. 5. A single typical cell of an interior filament showing chromatophore, pyrenoid, etc.×1040. 6. Exterior filaments showing sporangia in terminal clusters and a single lateral sporangium×670. 7. Short exterior filaments×670. 8. A branched exterior filament showing lateral and terminal sporangia (one of the emptied lateral sporangia is apparently being refilled or regenerated from the supporting vegetative cell)×670. 9. A short exterior filament showing regeneration of a terminal sporangium×670. 10. Part of a plant showing mode of branching and tortuous course of a part of an interior filament, etc.×670. 11. A short exterior filament bearing immature and emptied sporangia×670. 12. An unusually long exterior filament showing long hairs and short secund branchlets (solitary or in pairs)×670. Drawings by M. A. Howe, from Howe and Hoyt, 1916.

PLATE CXIX: *Acrochætium affine;* 1. Spore attached to margin of the *Dictyota* thallus×415. 2. A spore that has developed a small accessory prostrate basal cell and is also beginning to send up an erect filament×415. 3. Base of a mature plant showing simple basal cell and two erect filaments, each of which branches from its lowest cell×415. 4. Base of a similar, though larger, plant with four primary erect filaments, each branched at its base, a small cystocarp shown at *a* ×415. 5. Base of a plant showing a scarcely enlarged basal cell, short creeping basal filaments, and a single erect filament which has two branches from its lowest cell×415. 6. A vertical section through the base of a plant, showing a few small accessory cells that partly cover the primary basal cell×415. 7. Base of a plant showing accessory basal cells and three coarse and three slender erect filaments, none of which branches from its lowest cell×415. 8. Base of a plant with accessory basal cells and erect filaments of various sizes×415. 9. Base of a plant that has developed a small imperfect basal disk, with the original spore still evident×415. 10. Optical section of the margin of the Dictyota thallus showing base of a young plant with a single immersed basal cell and a single erect filament×415. 11. Optical section of the base of a plant showing subpyriform semi-immersed primary basal cell and several superficial smaller secondary cells, some of which send up erect filaments×415. 12. Section through the margin of the Dictyota thallus showing single subpyriform basal cell with penetrating foot×415. 13. Base of a detached plant showing primary basal cell, its penetrating foot, three erect filaments, and two small accessory basal cells×415. 14. Section of margin of the Dictyota thallus showing four basal cells of approximately equal size that are more or less immersed×415. 15. A sporangium terminal on a main branch×415. 16. Sessile lateral sporangia×415. 17. A sporangium on a one-celled pedicel×415. 18. Procarp and antheridia×670. 19. An older procarp with no antheridia apparent in its vicinity×670. 20. A cystocarp×670. 21. A typical cell from one of the coarser filaments×670. 22. A typical cell from one of the more slender filaments×670. Drawings by M. A. Howe, from Howe and Hoyt, 1916.



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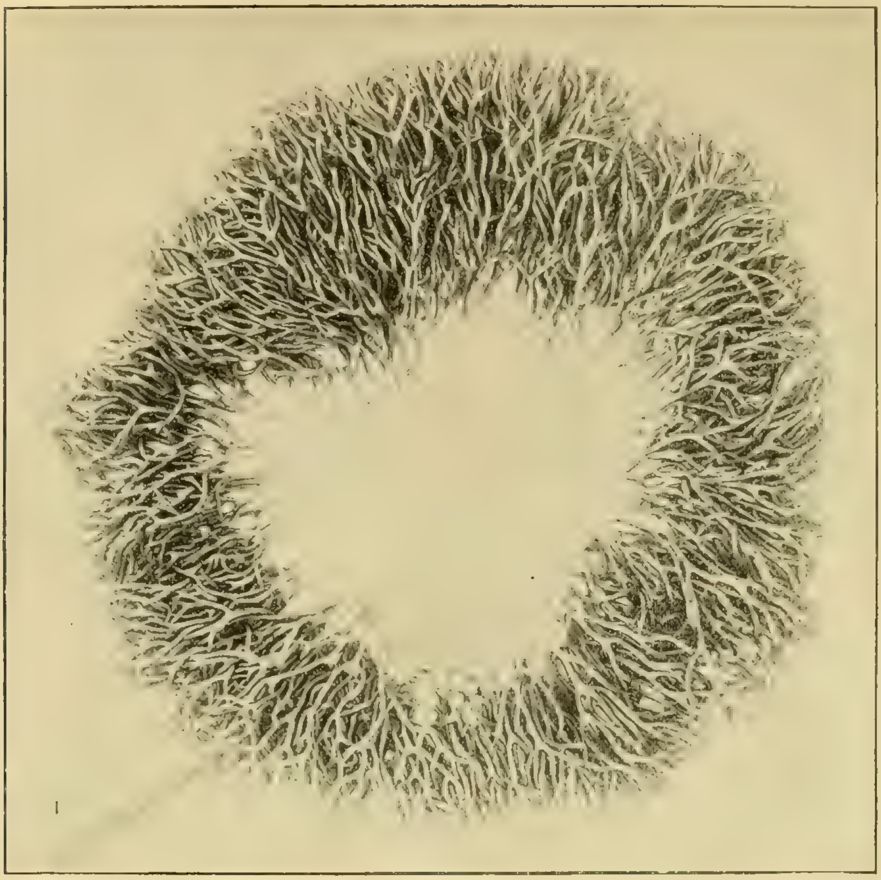
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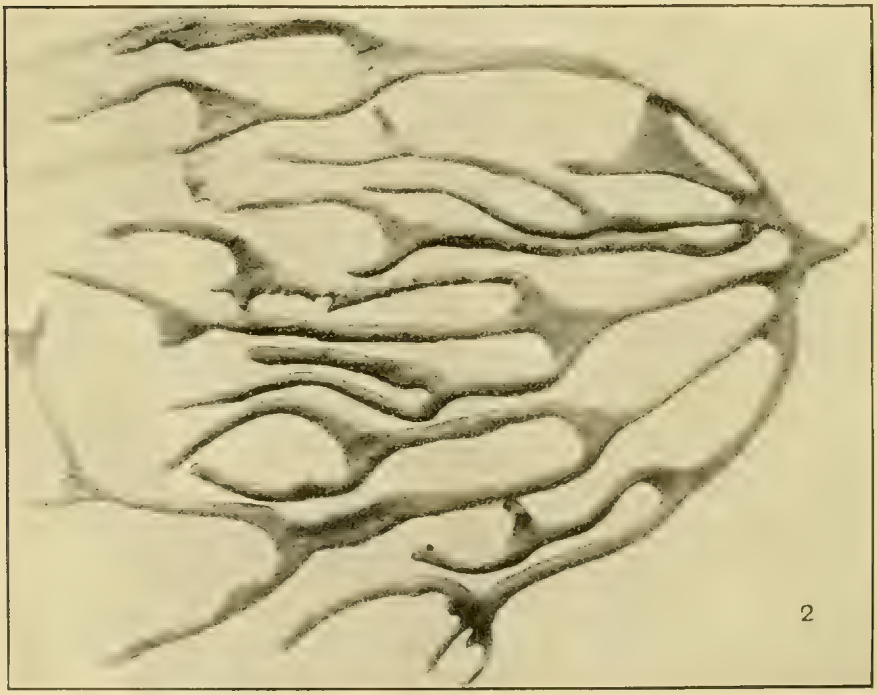
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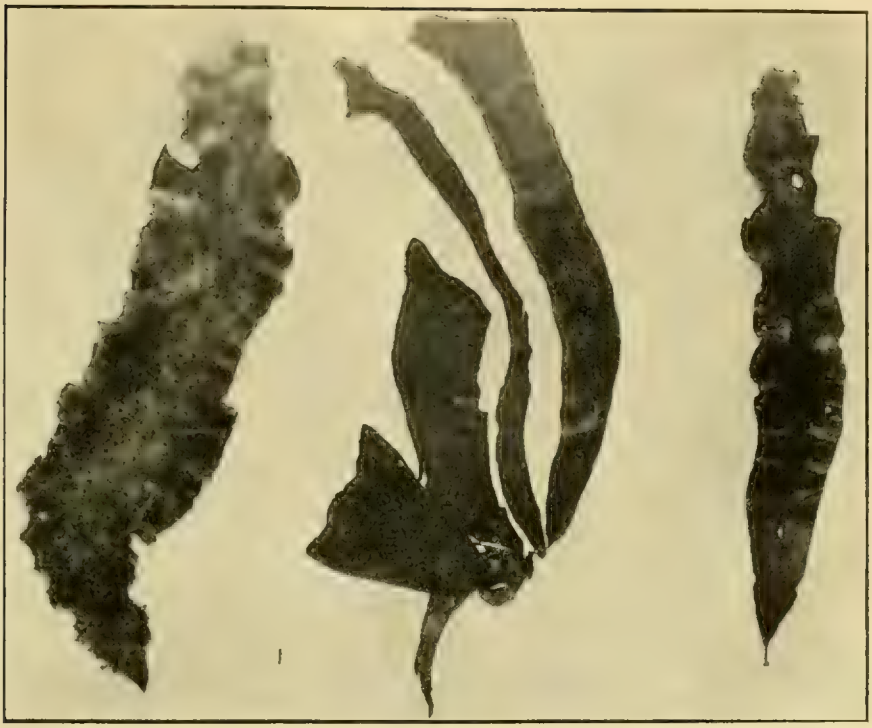

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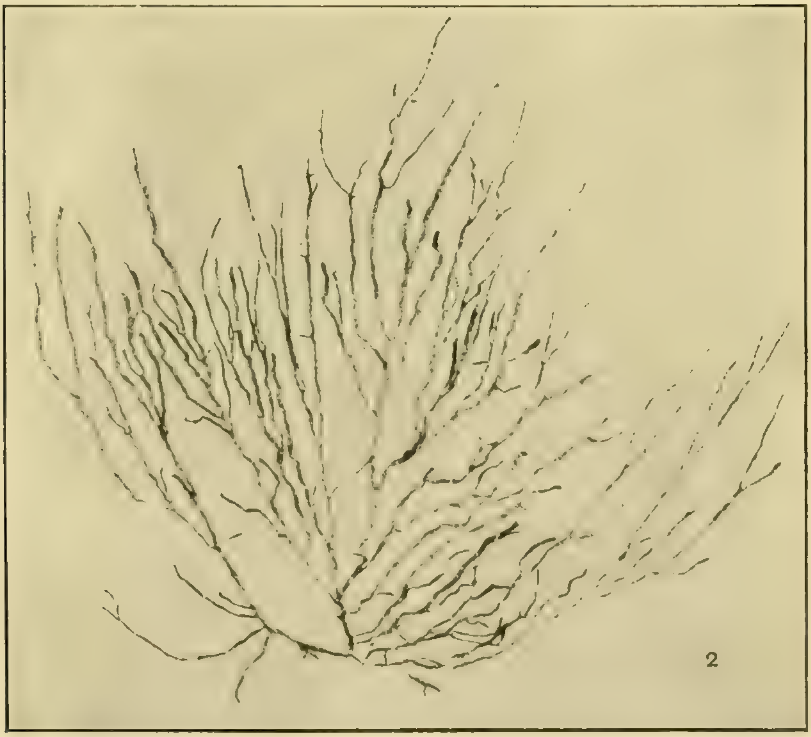

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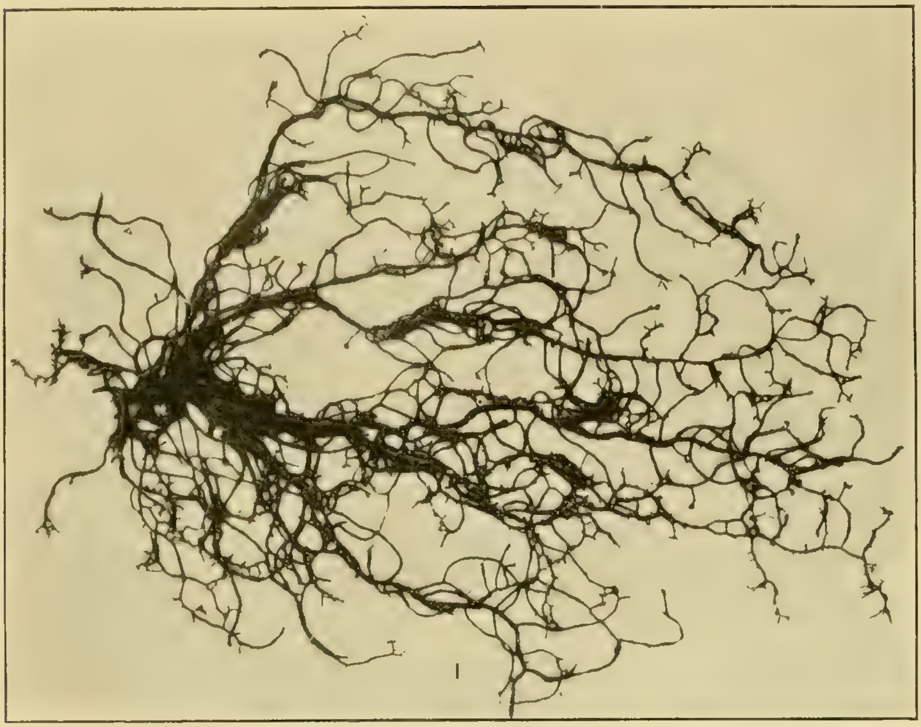

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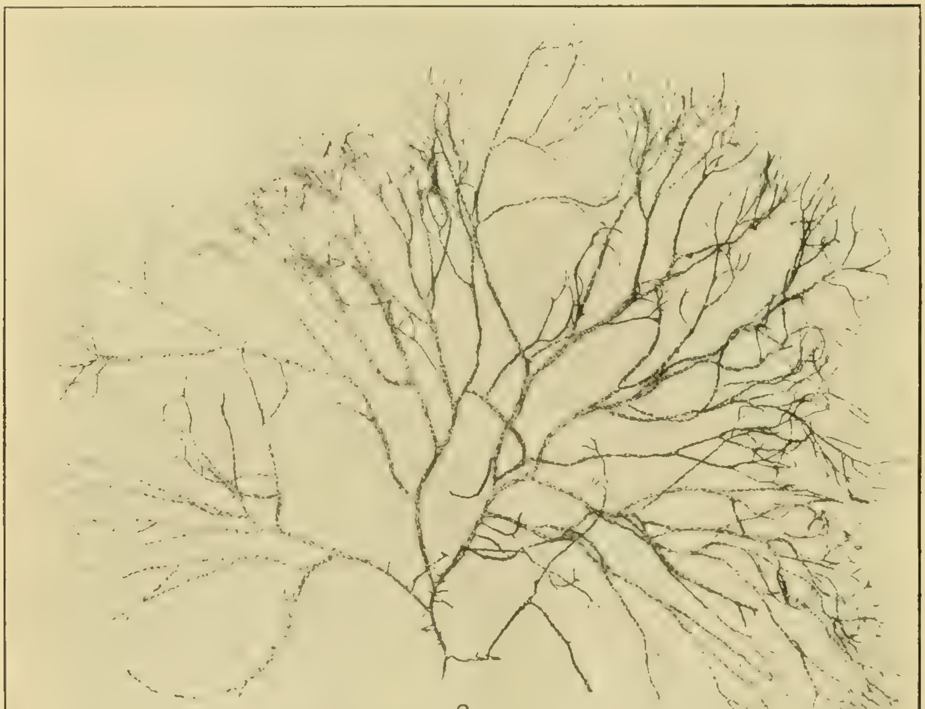

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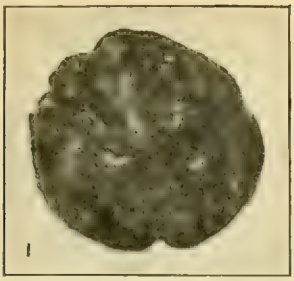
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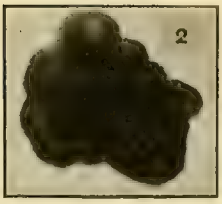
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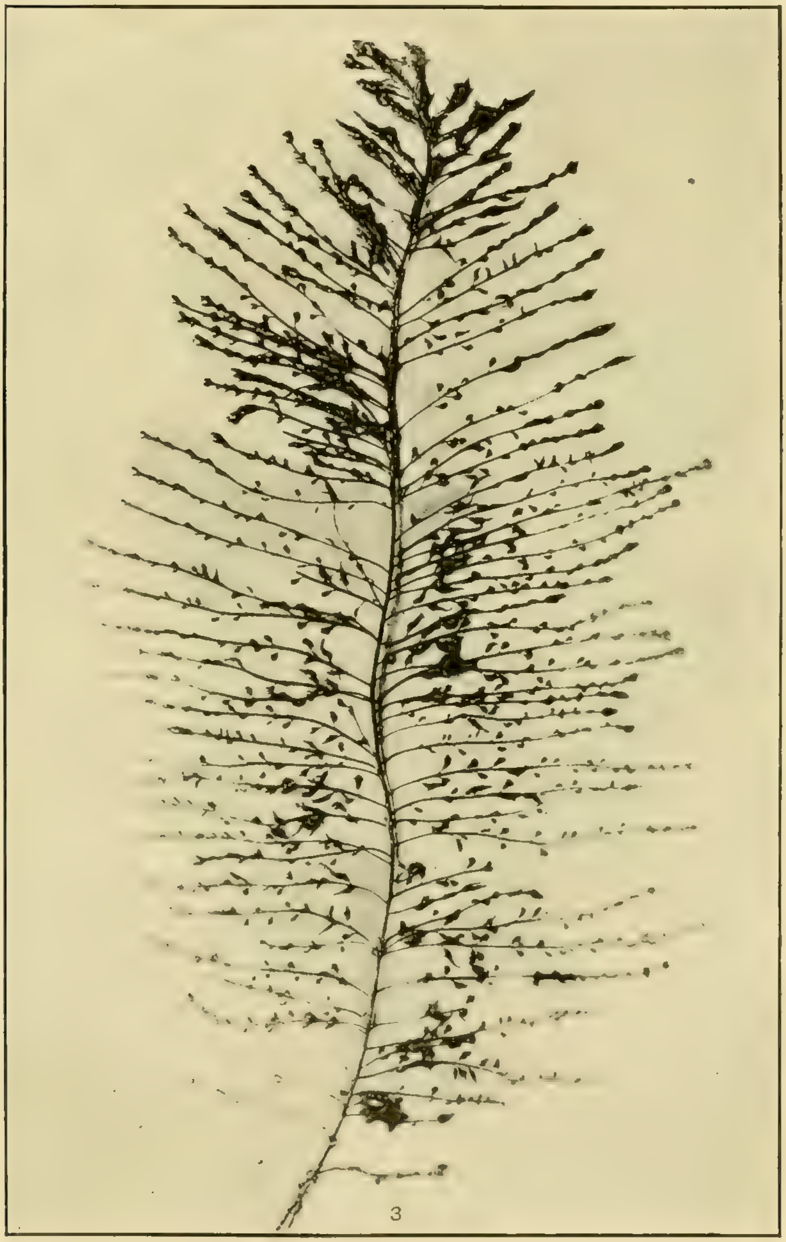
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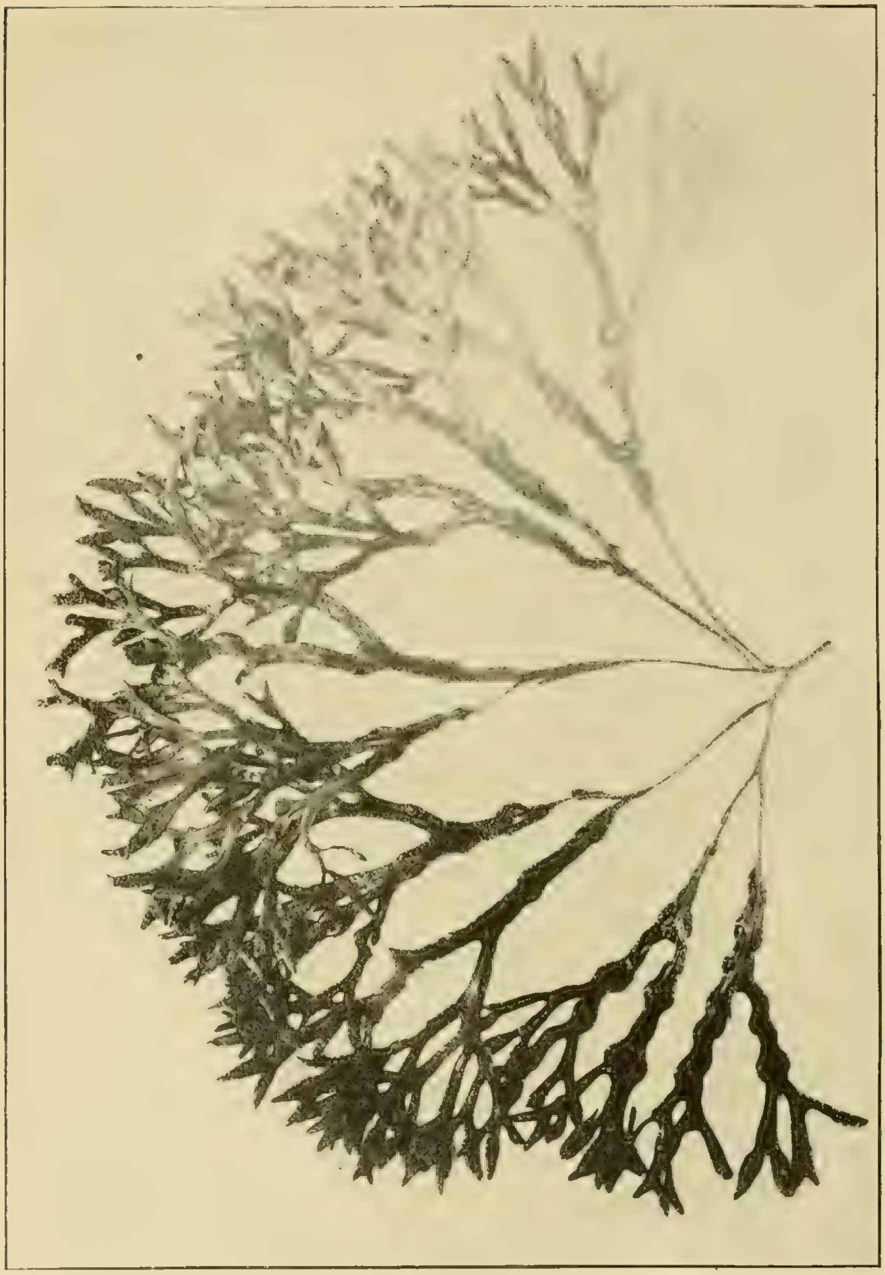

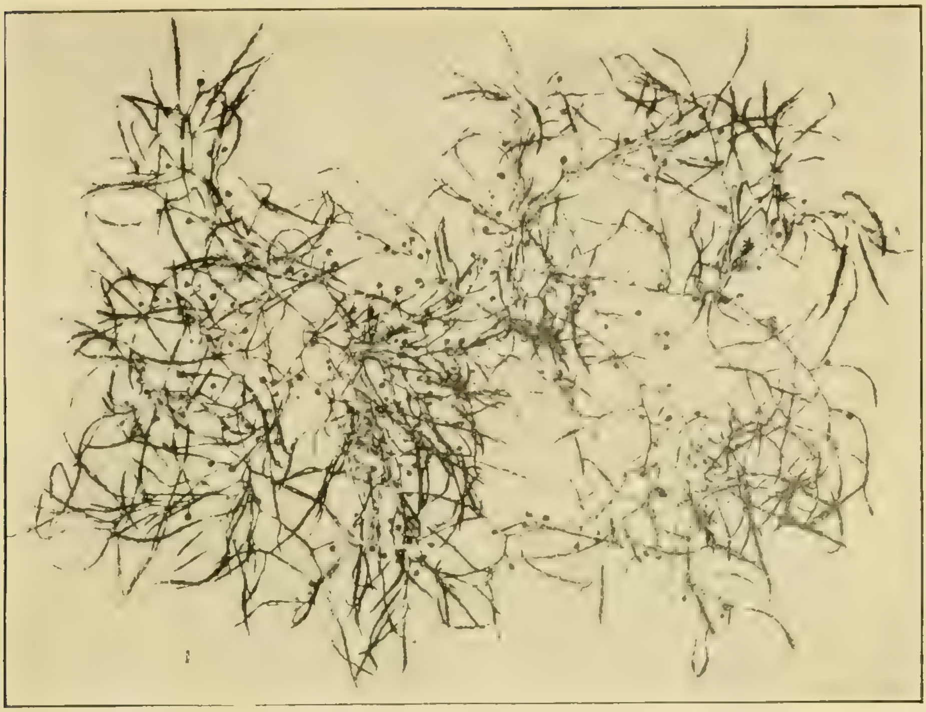

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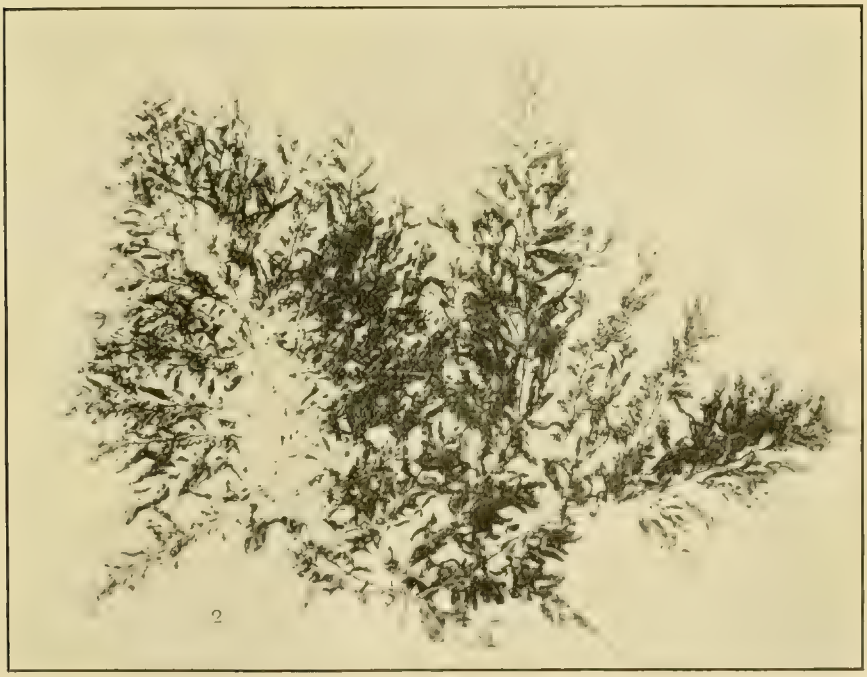

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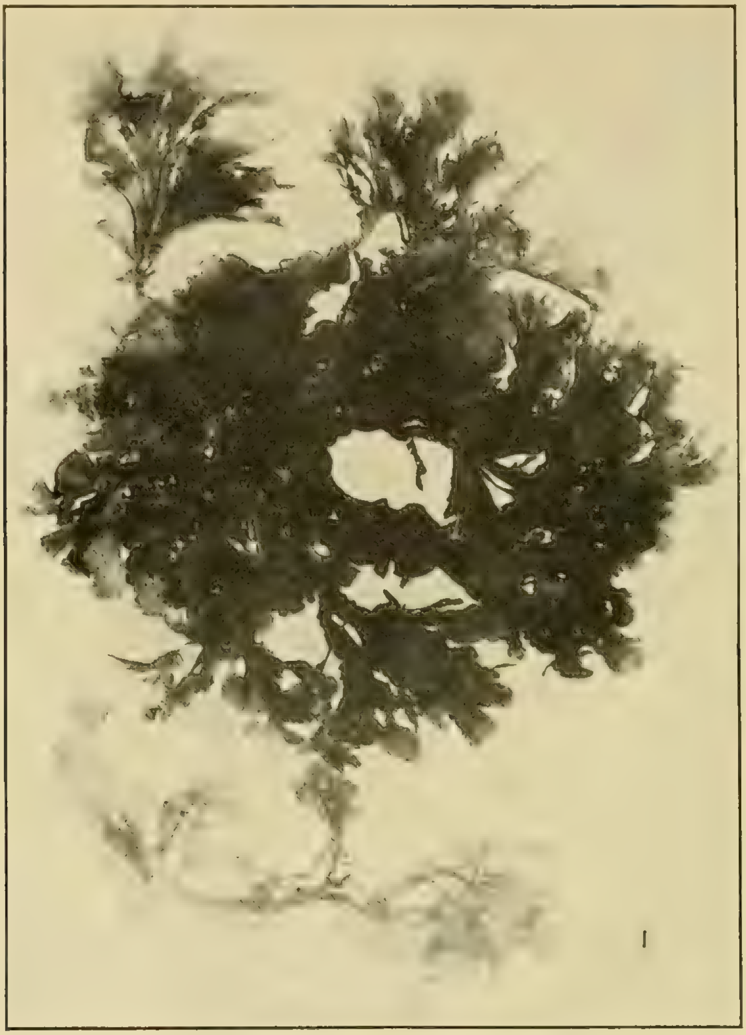

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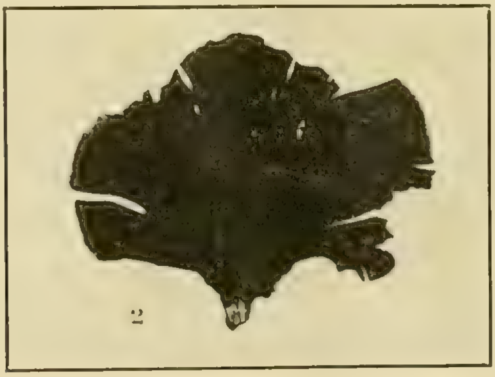

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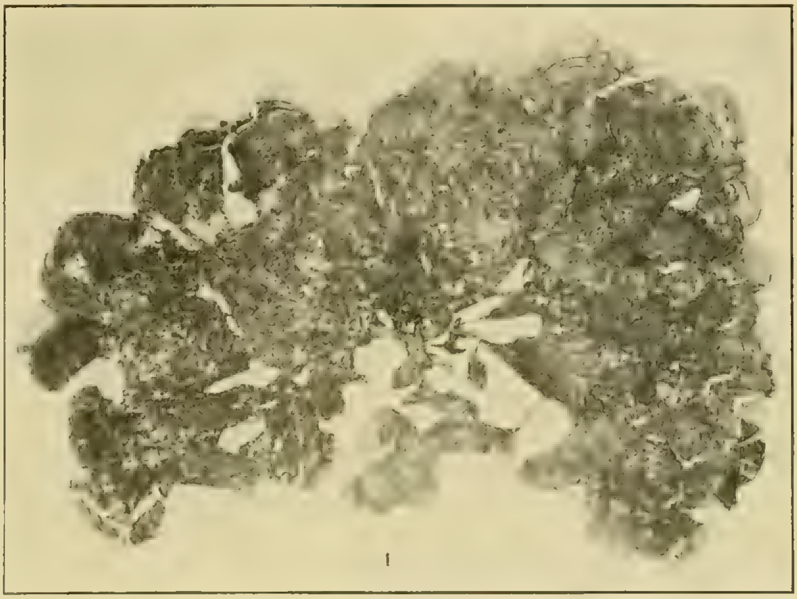

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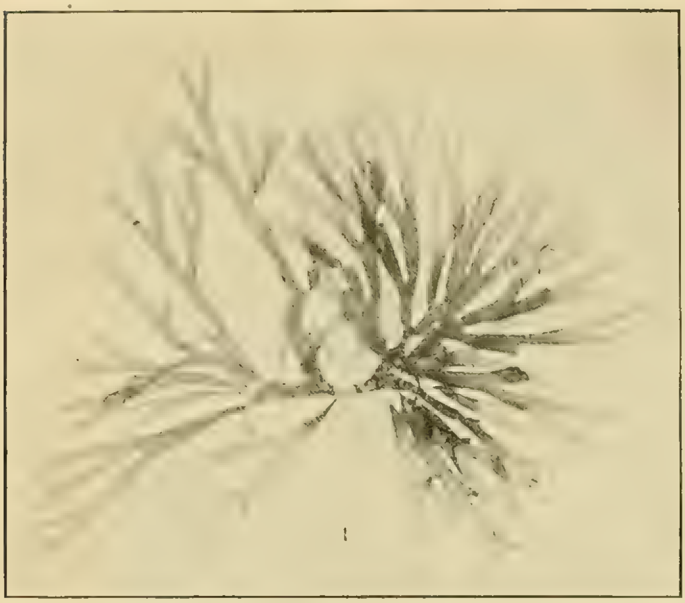
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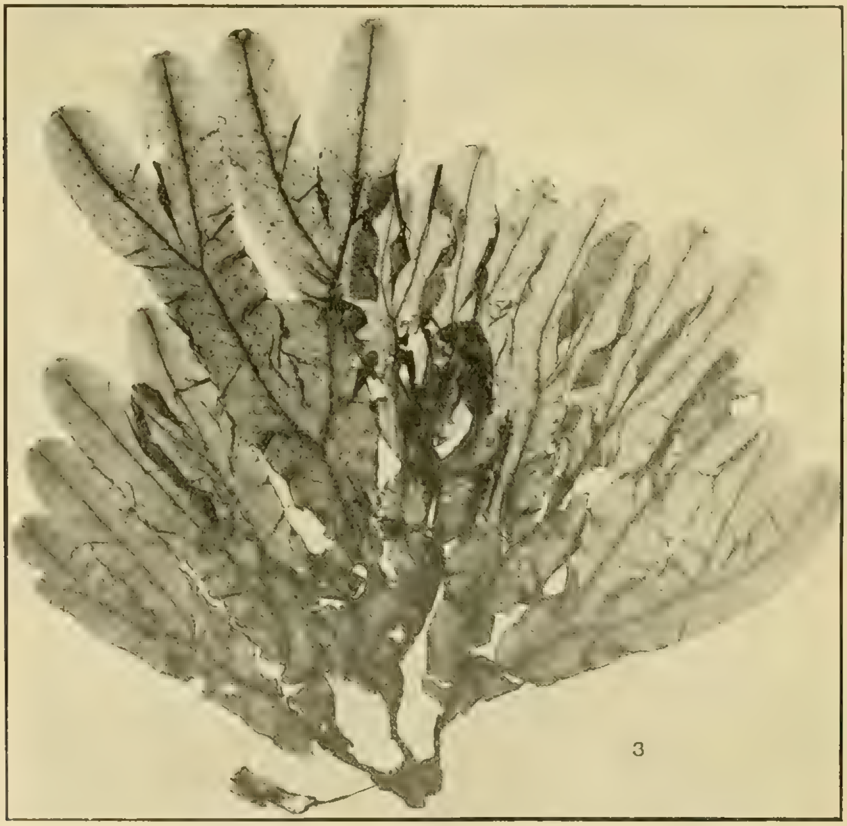
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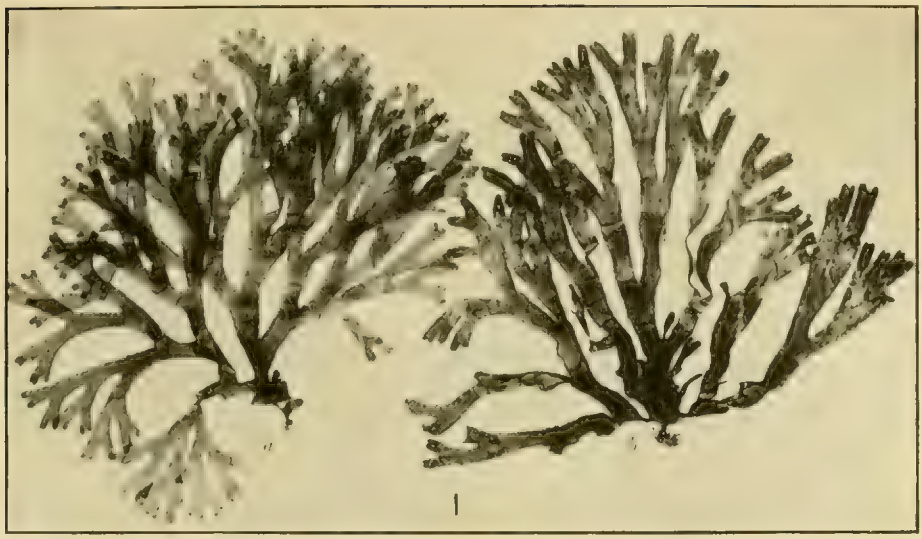

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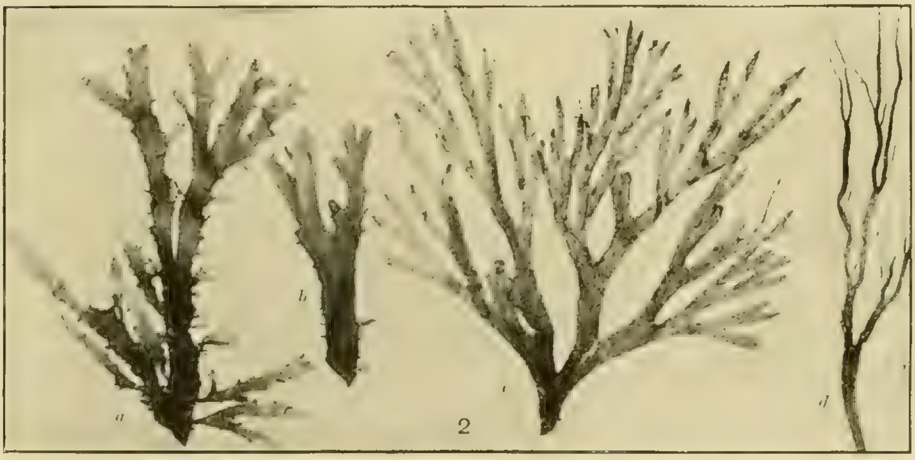

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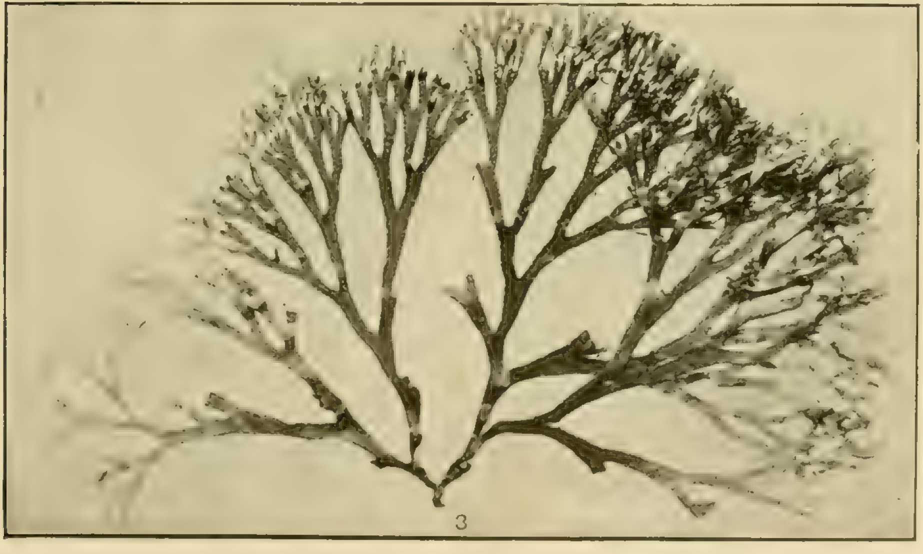

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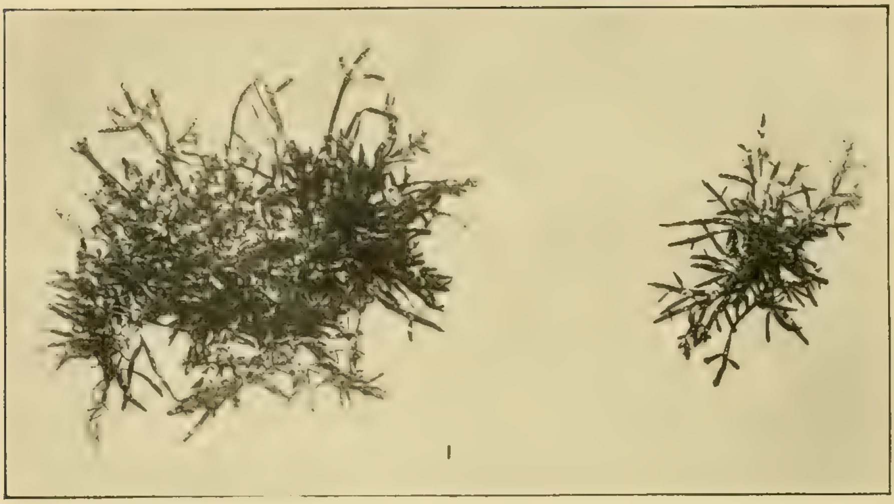

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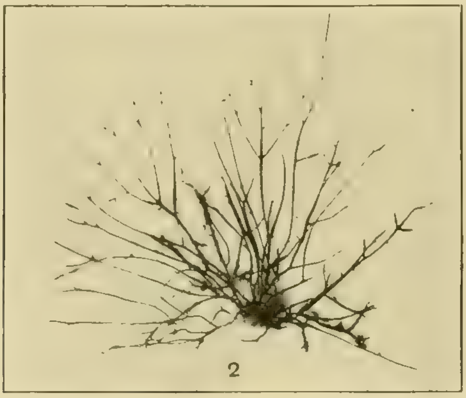

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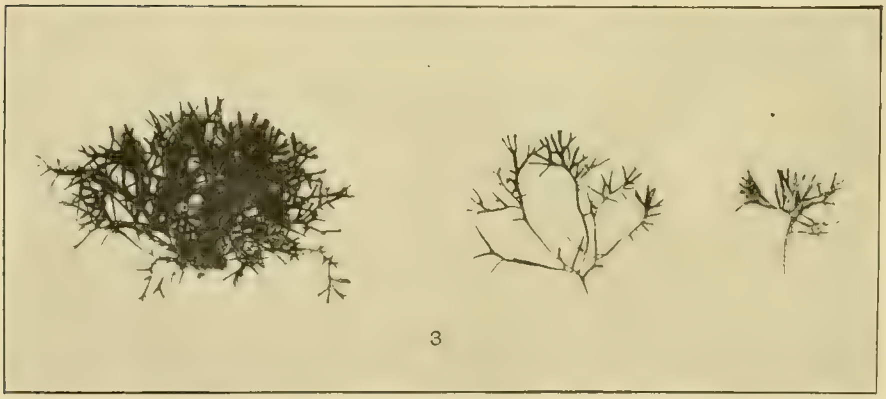

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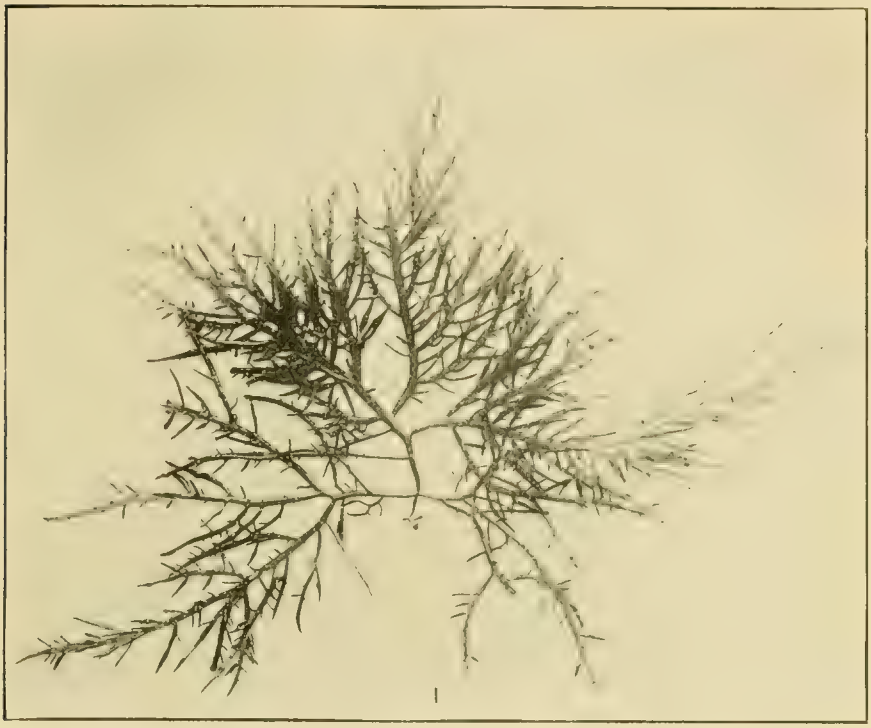

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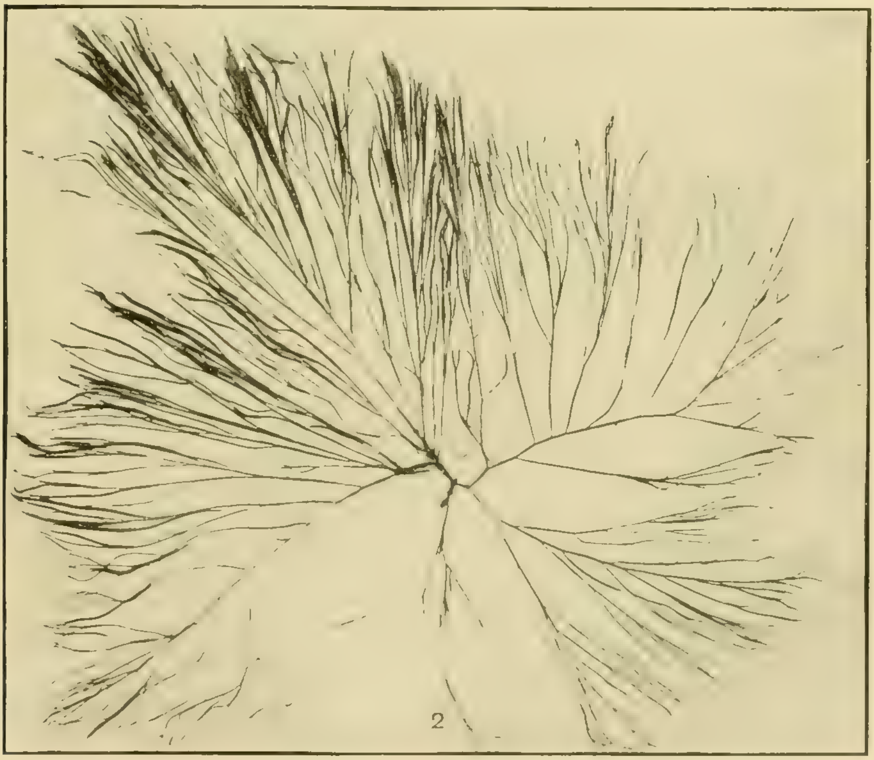

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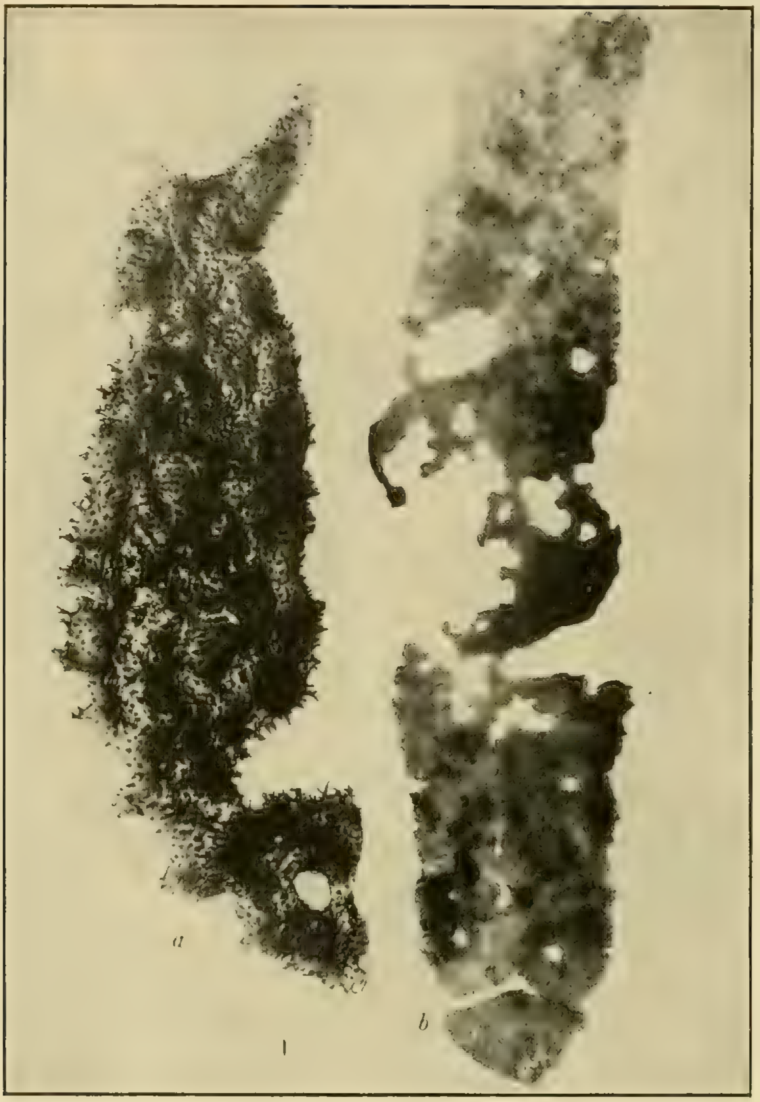

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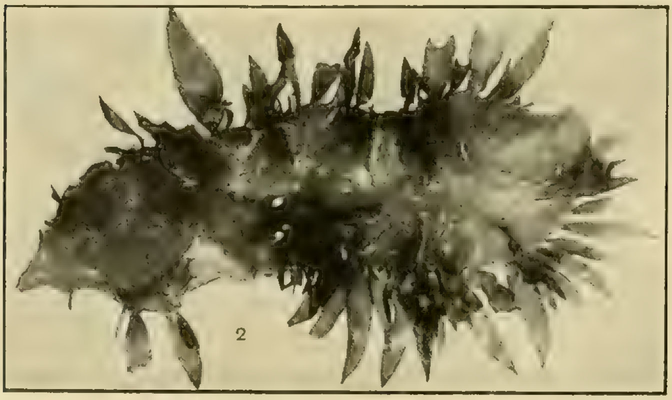

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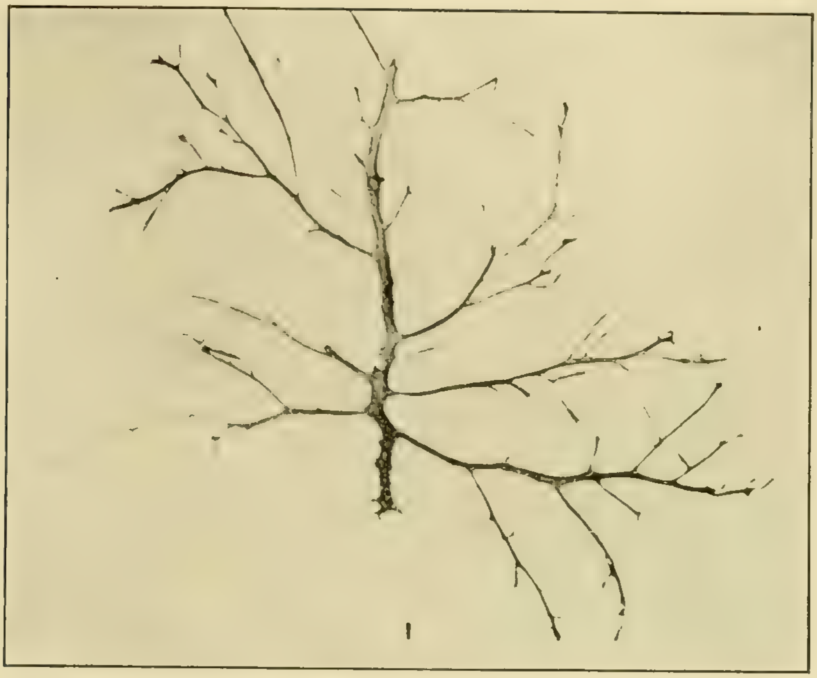

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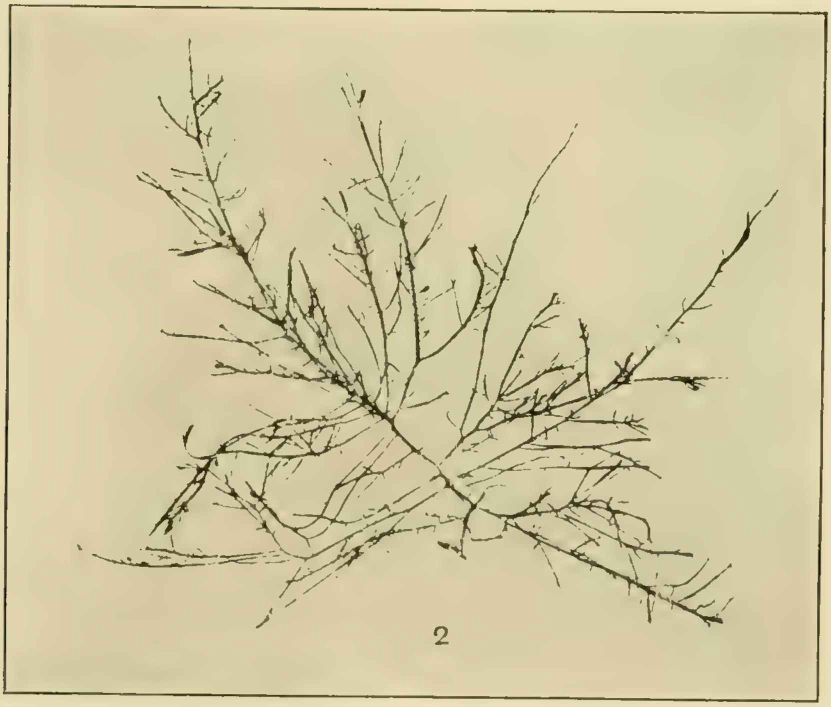

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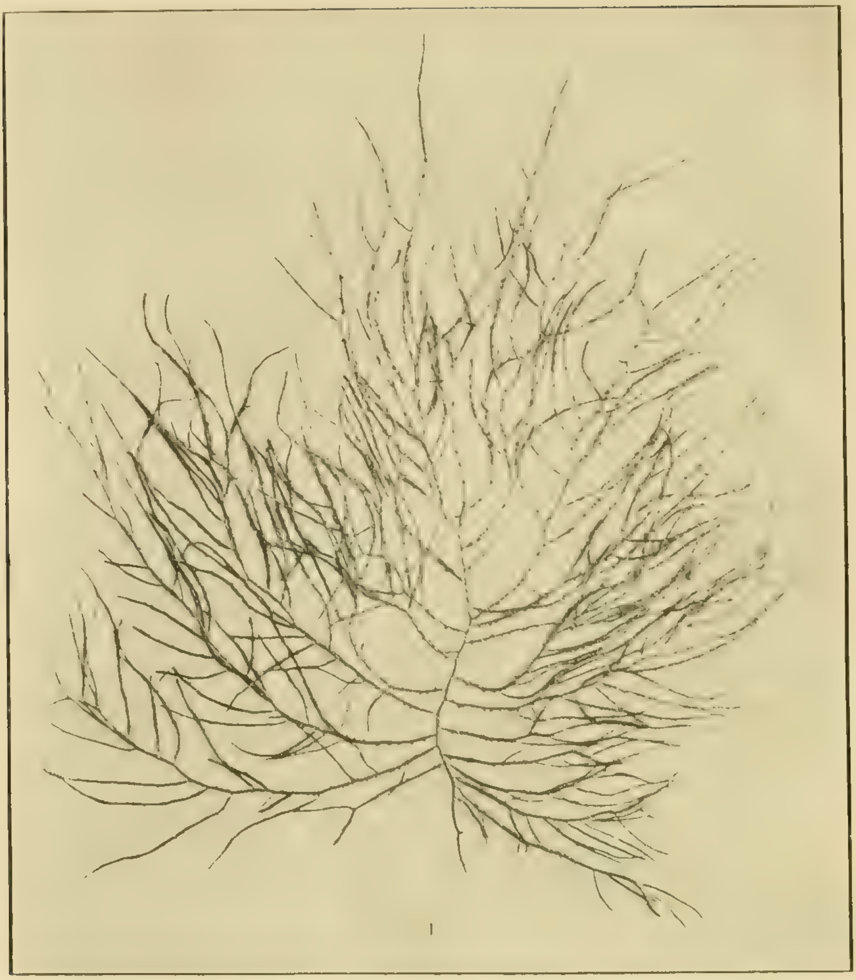

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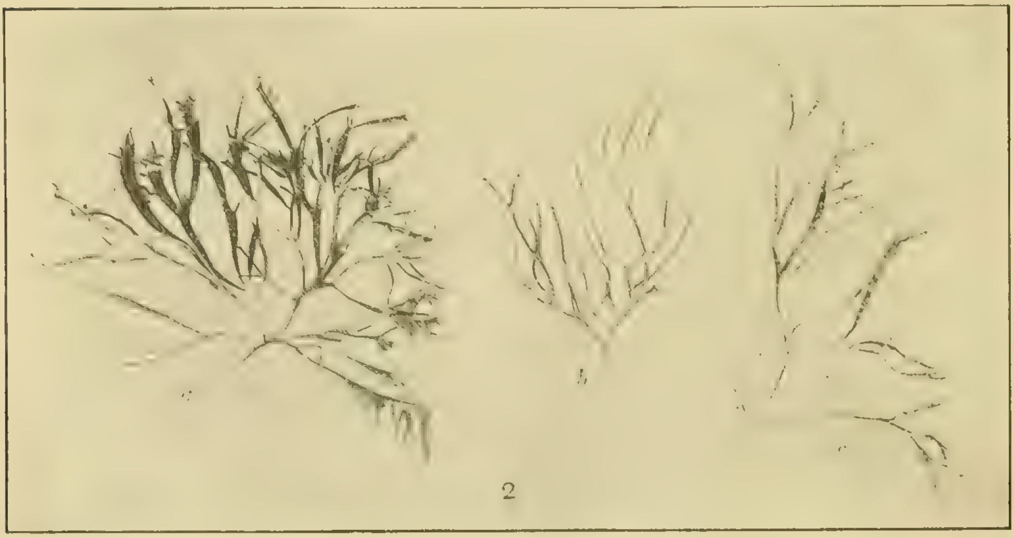

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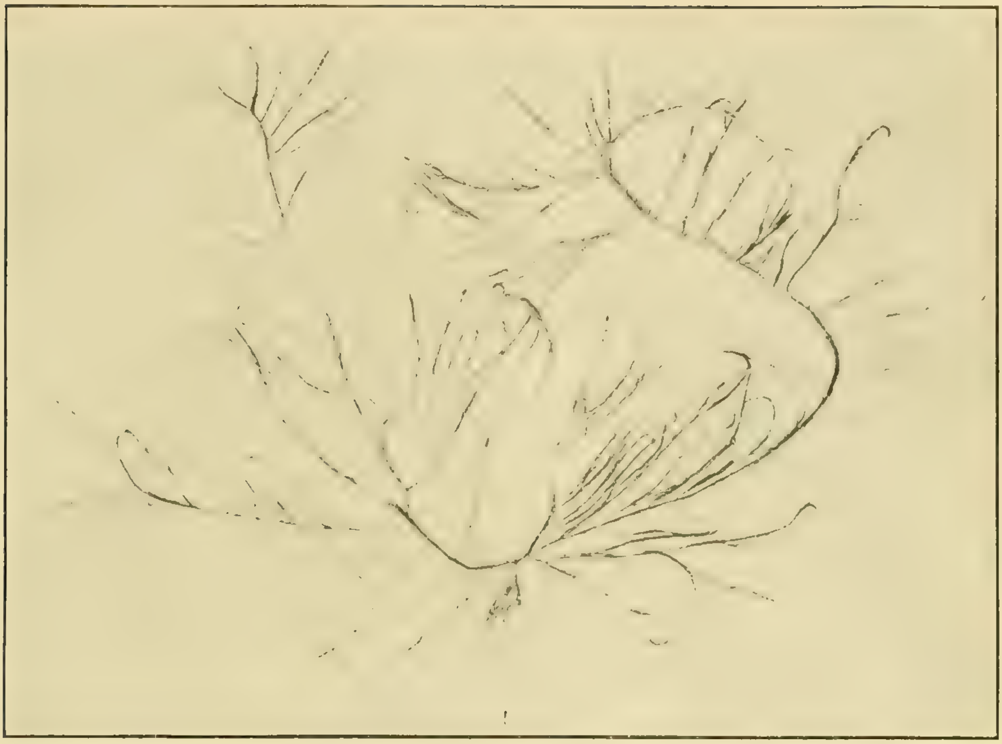

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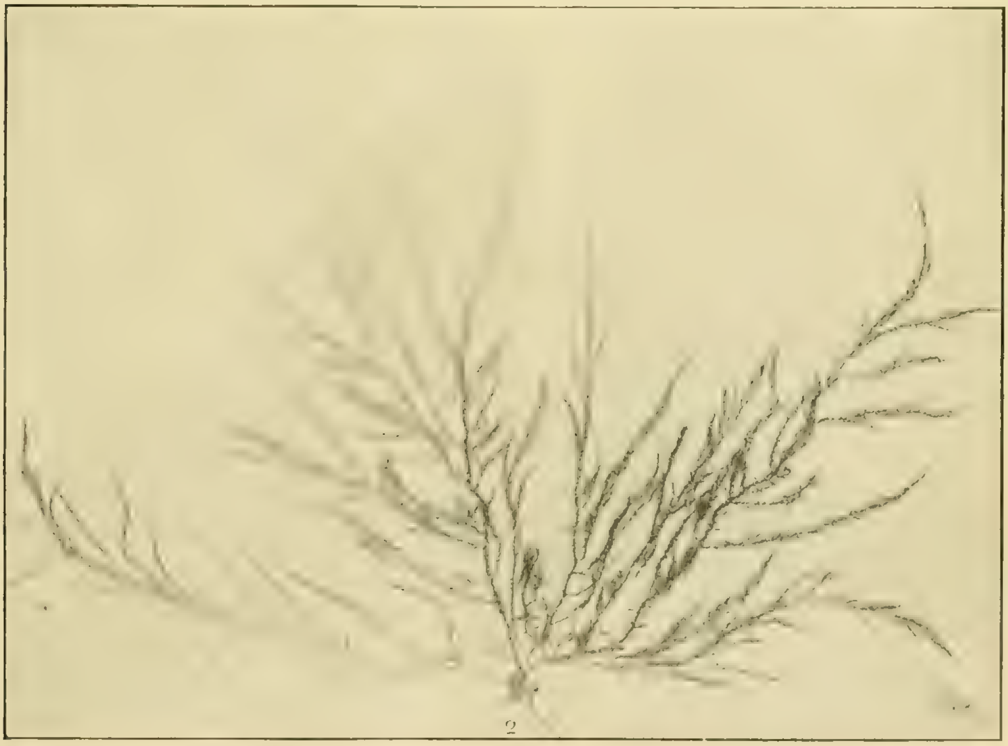

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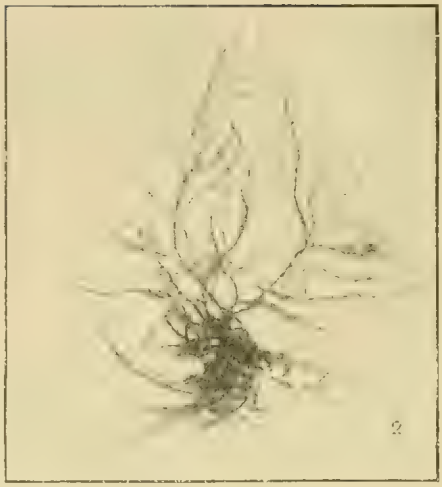
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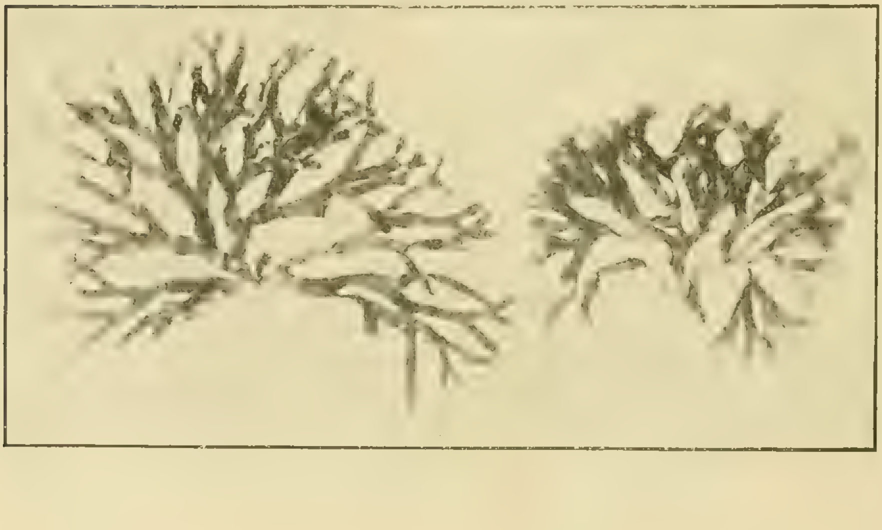

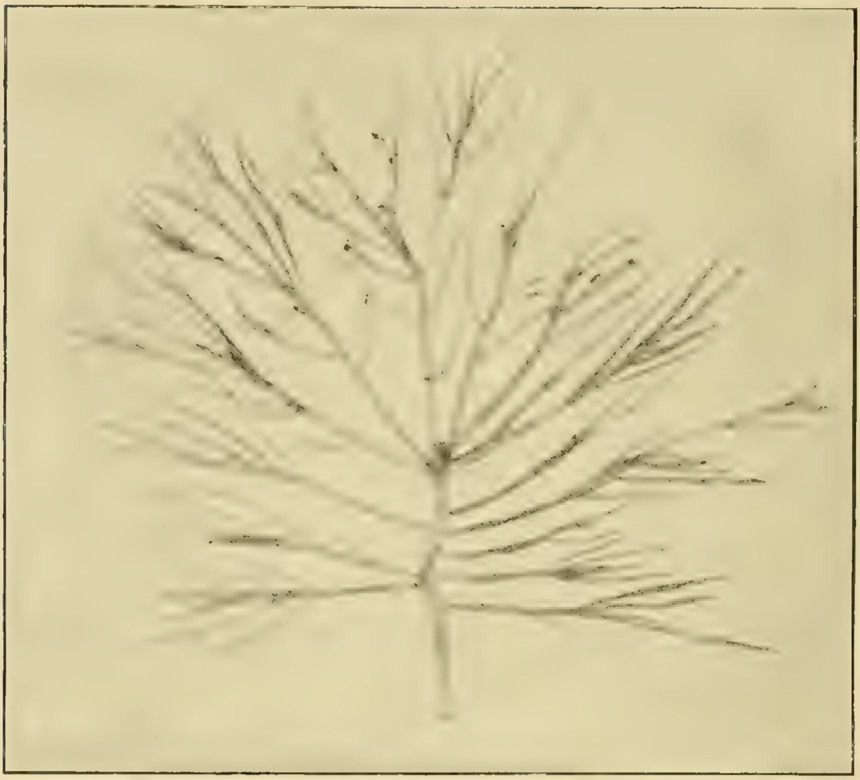

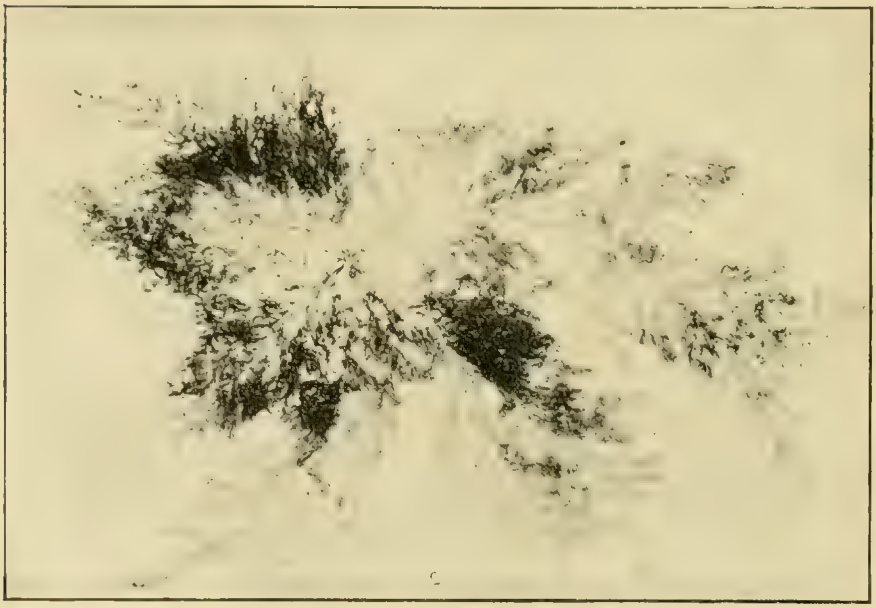

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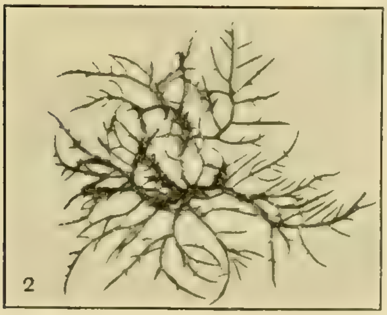

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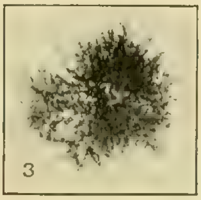

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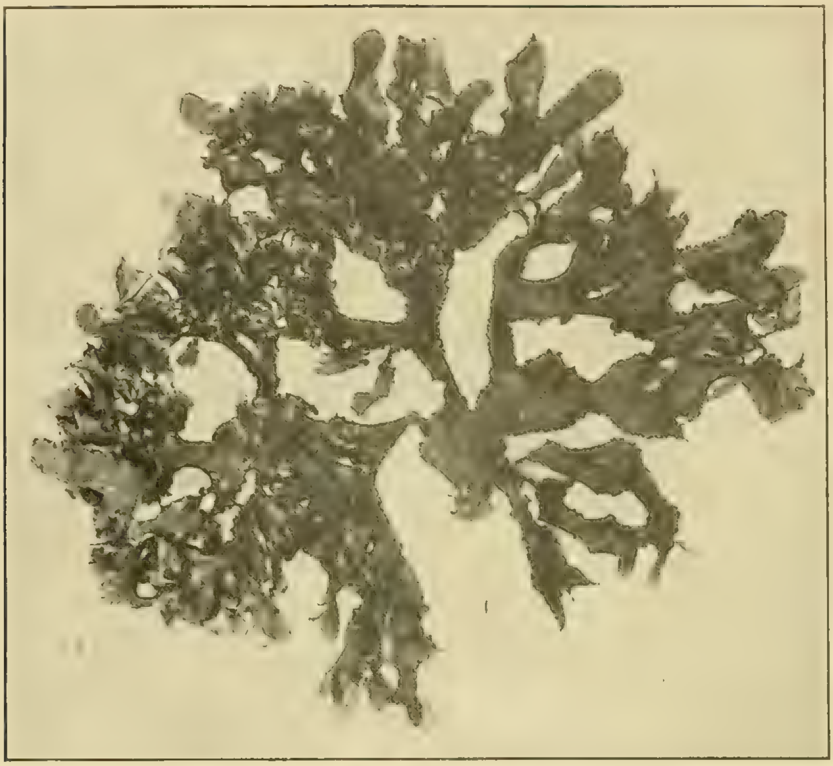
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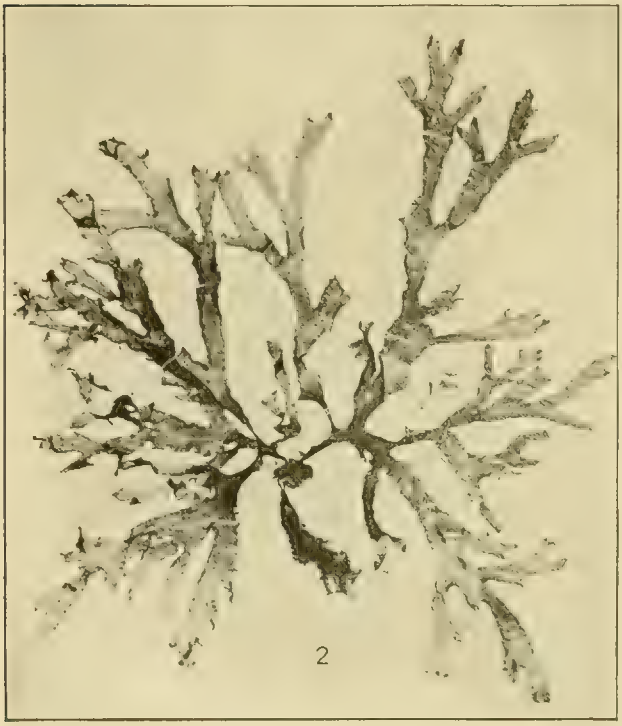
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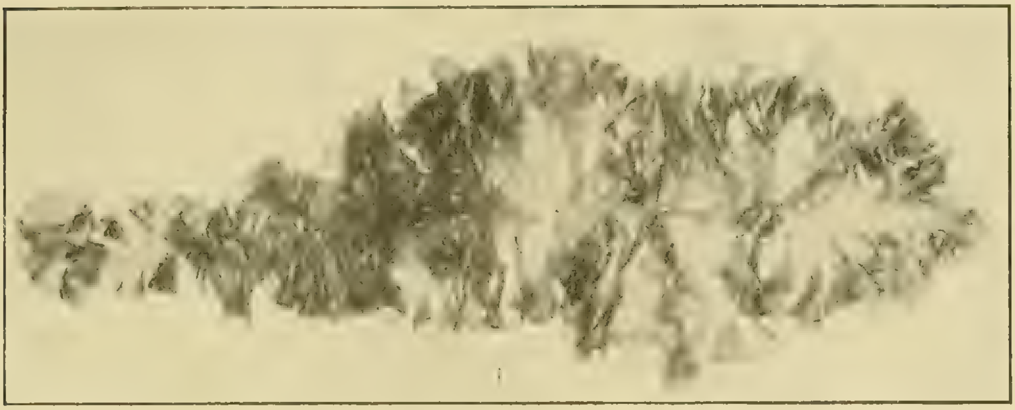

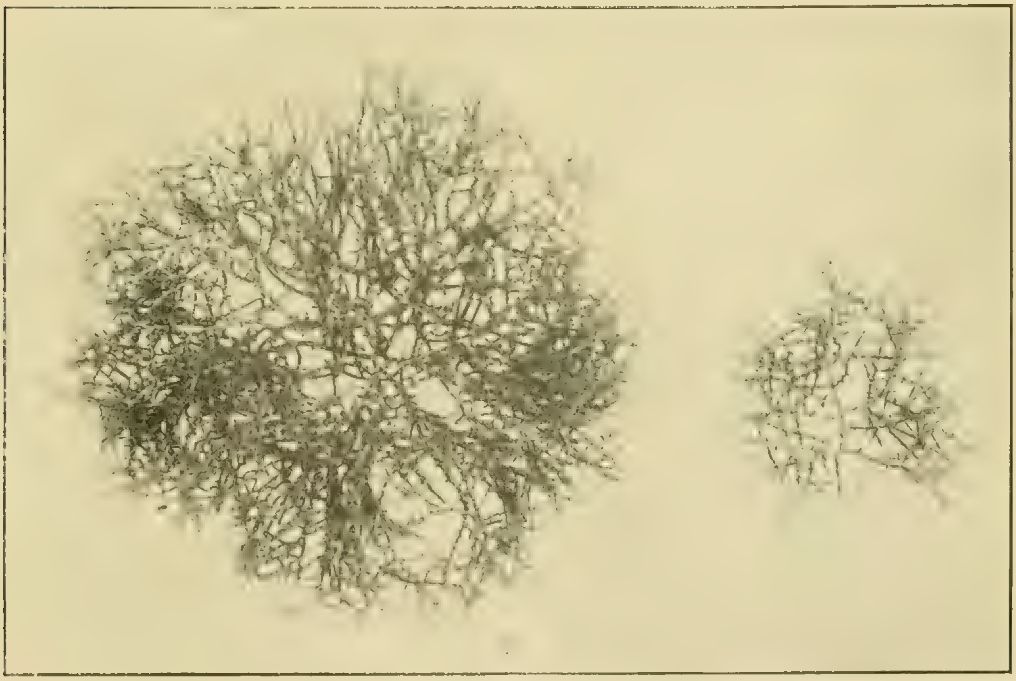

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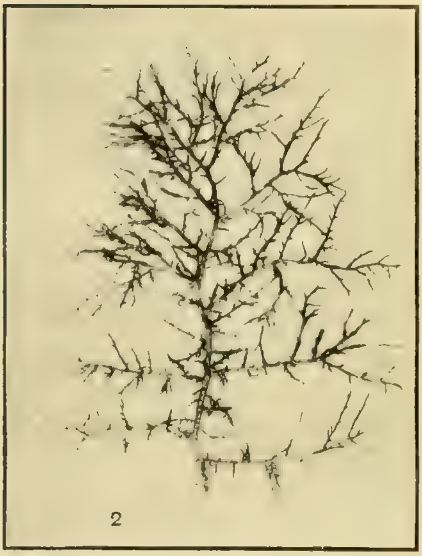

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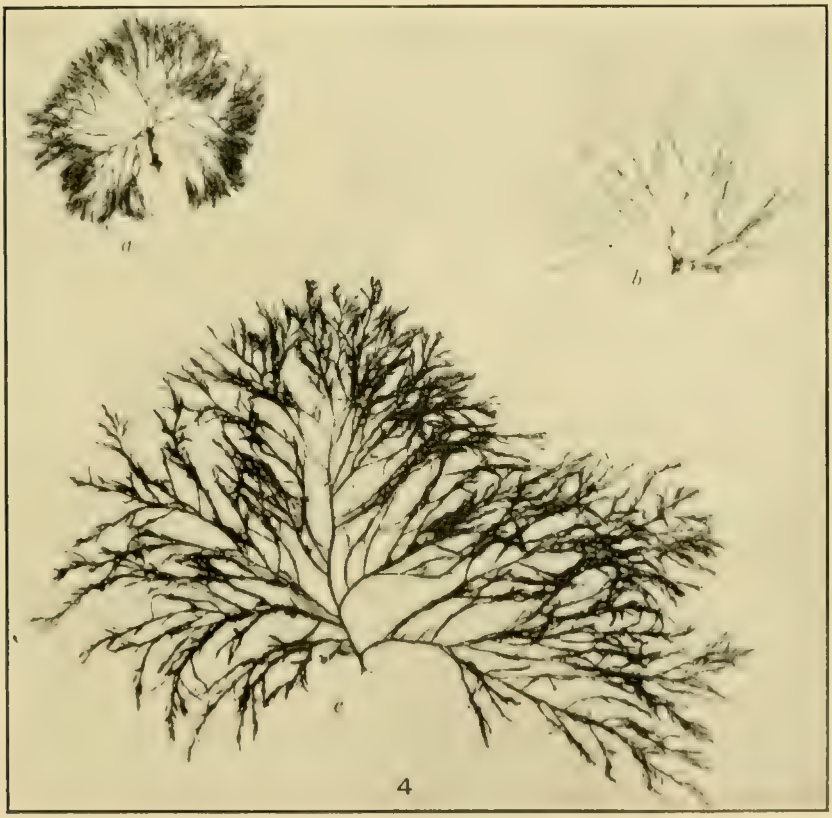

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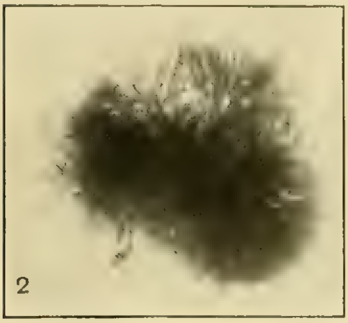
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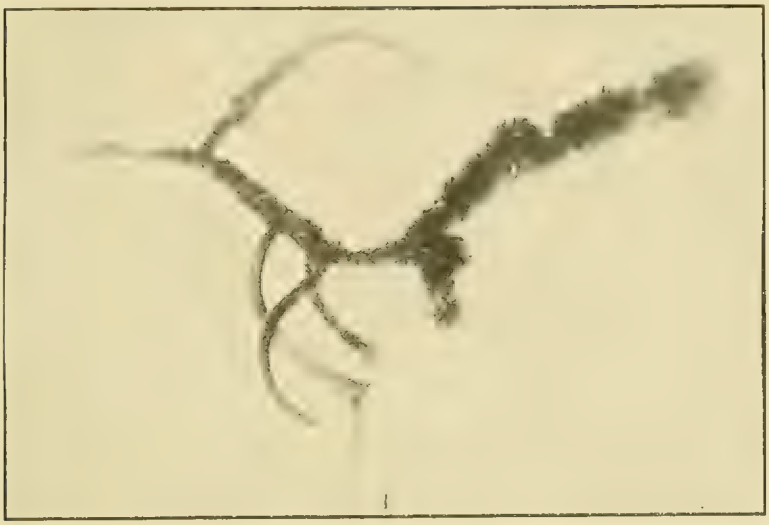

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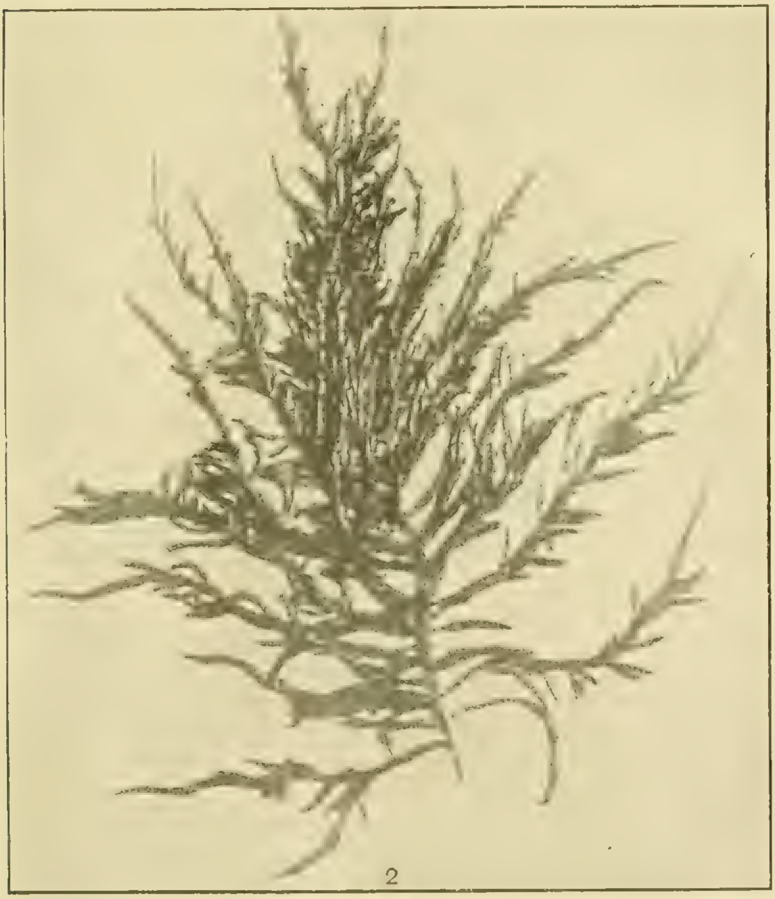

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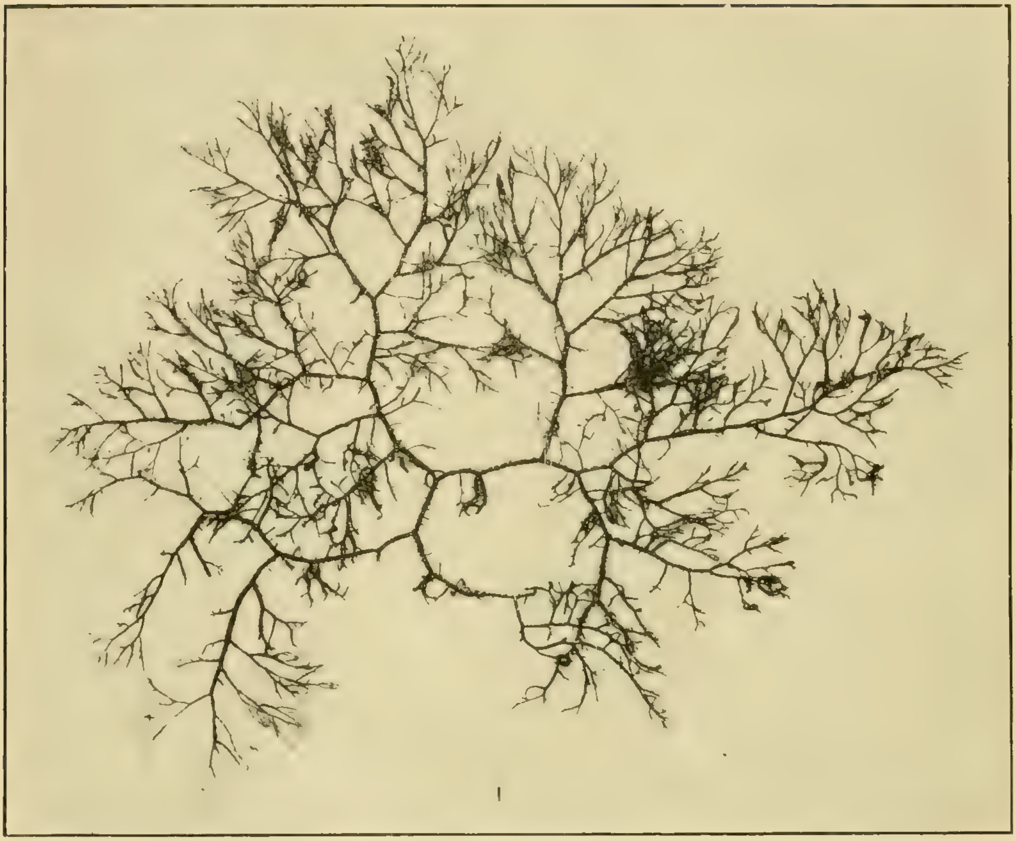

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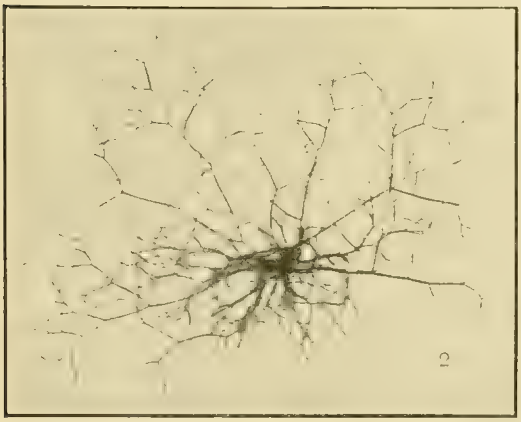

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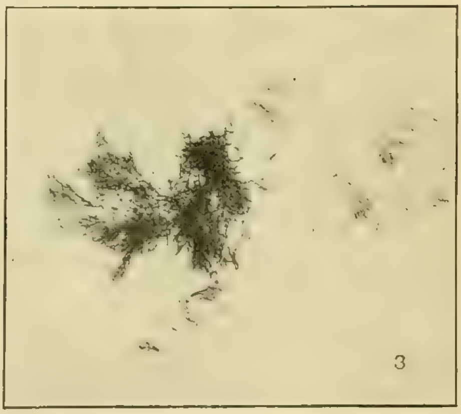

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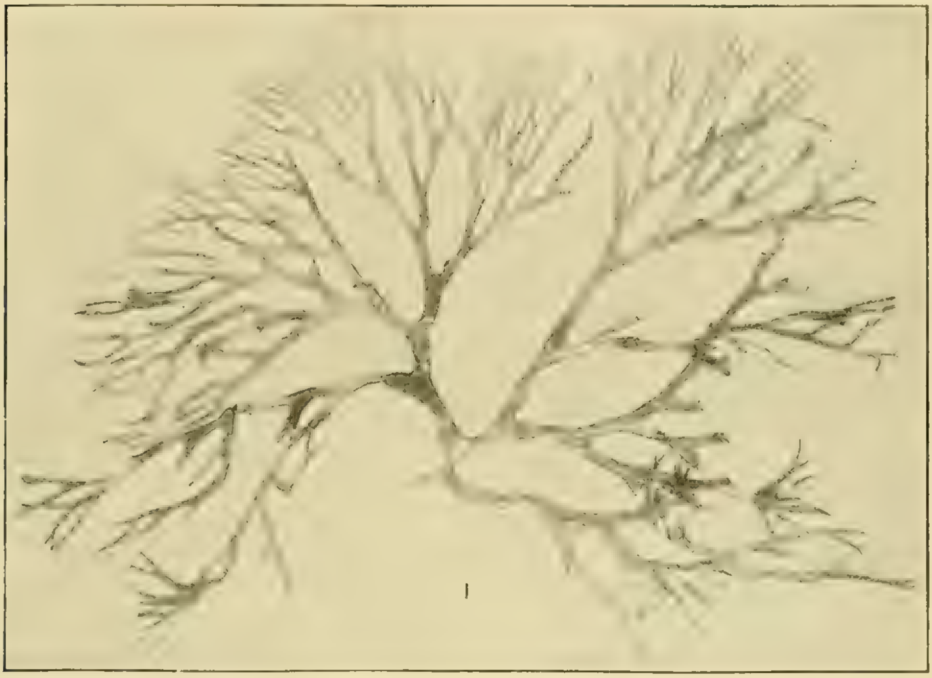
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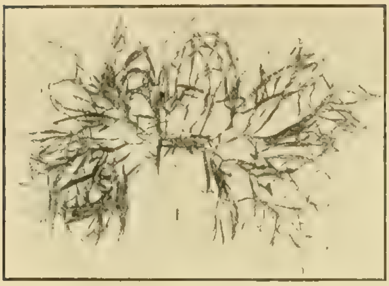

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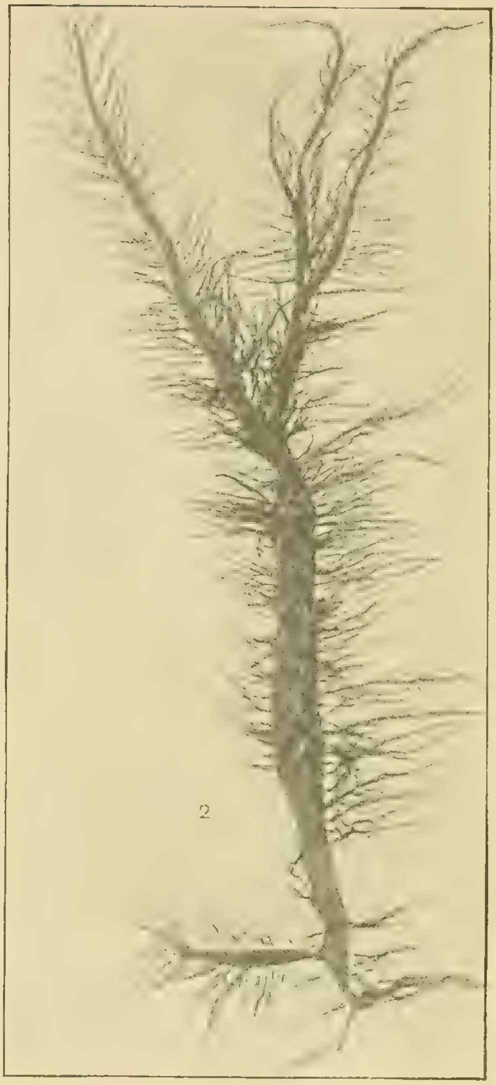

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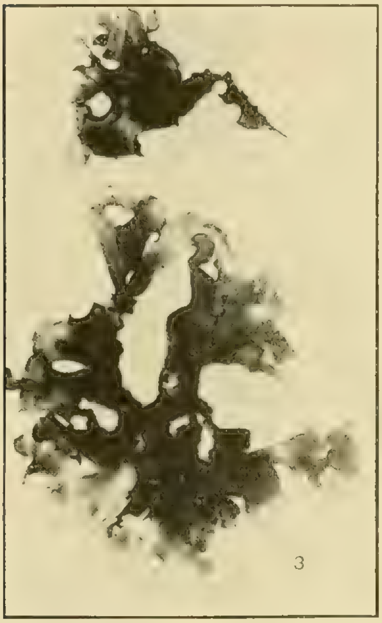

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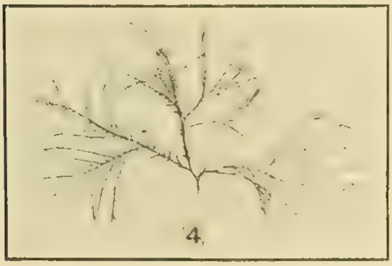

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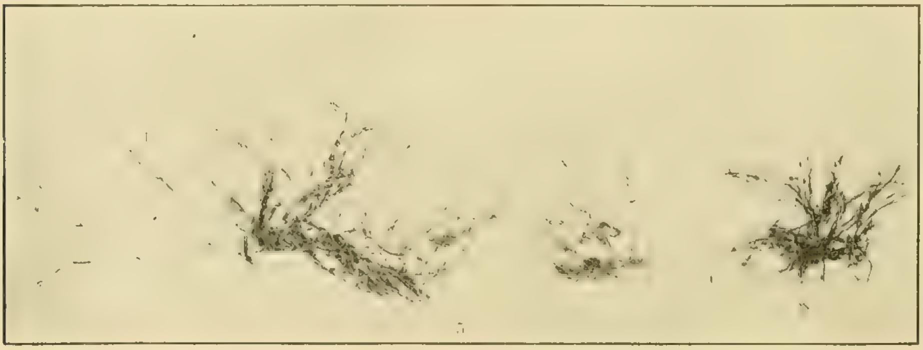

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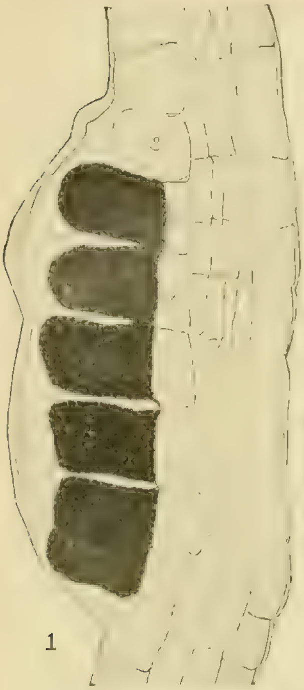
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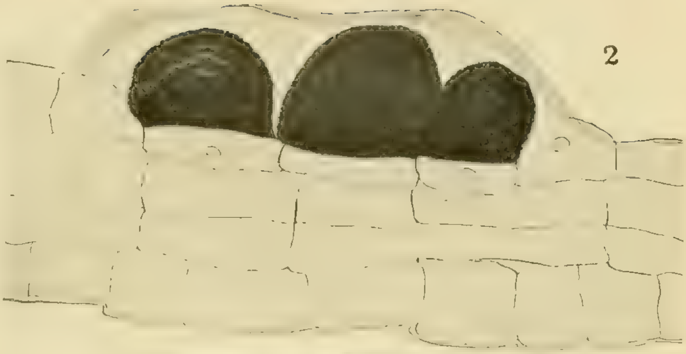
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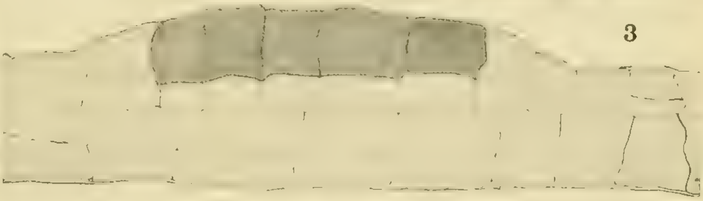
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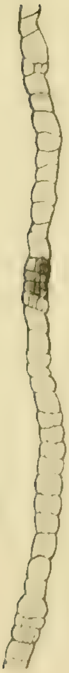
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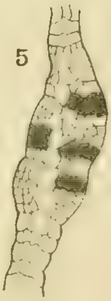
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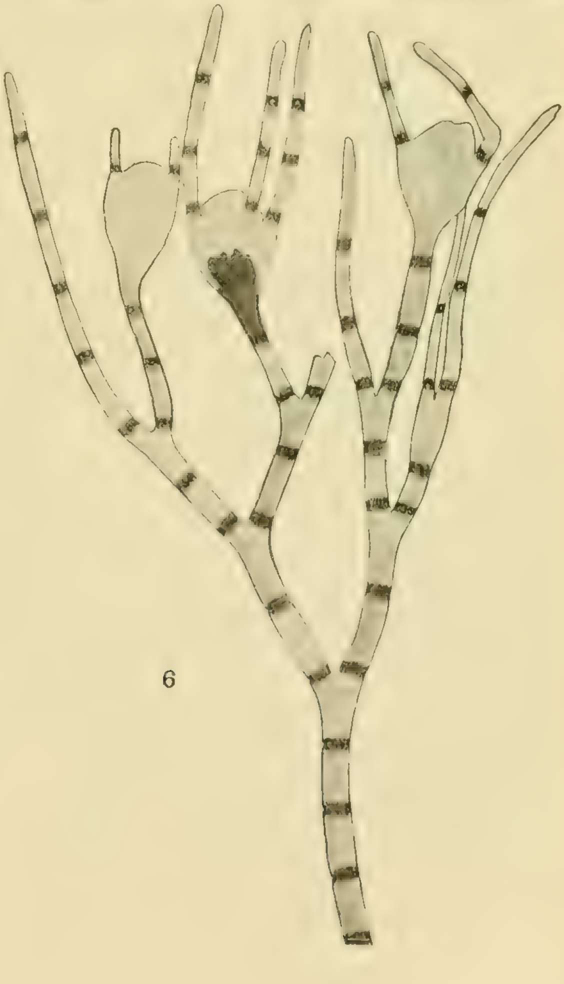
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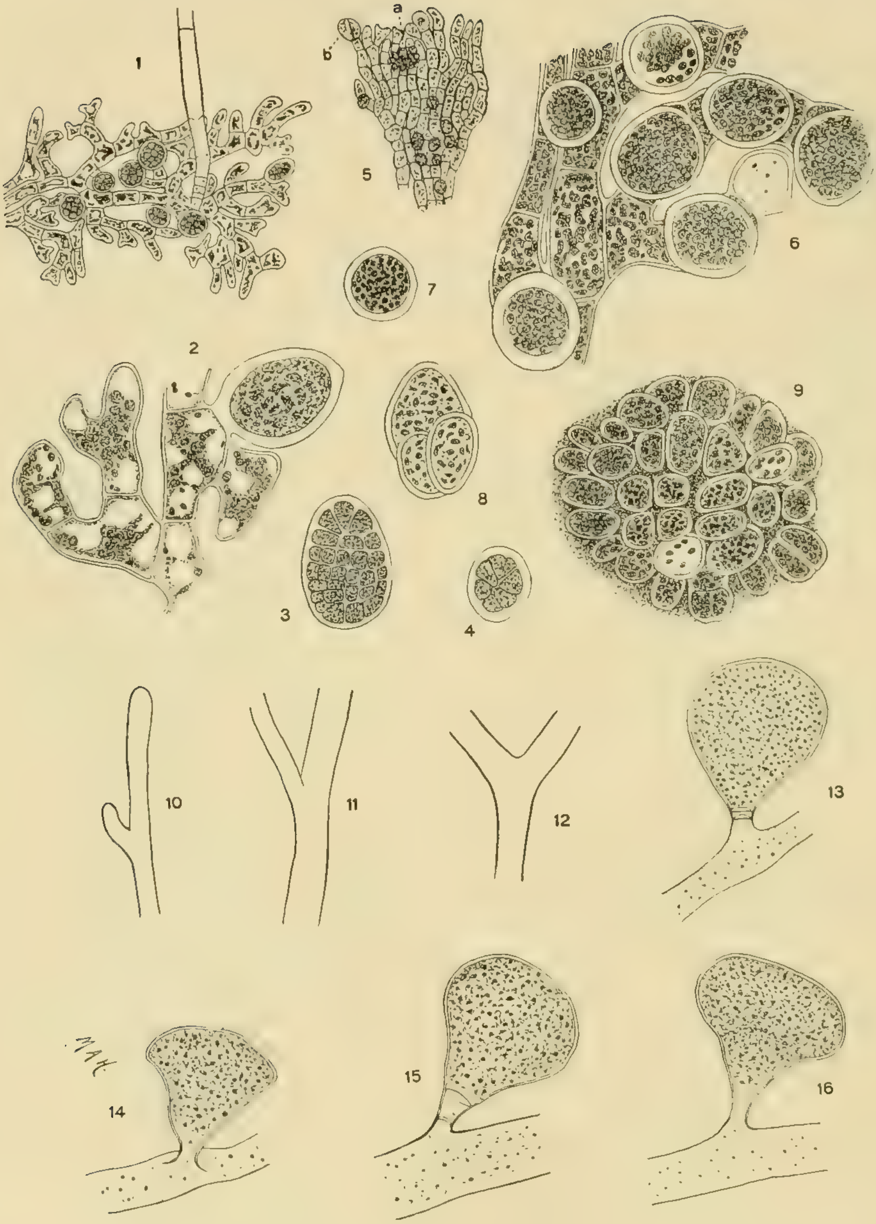
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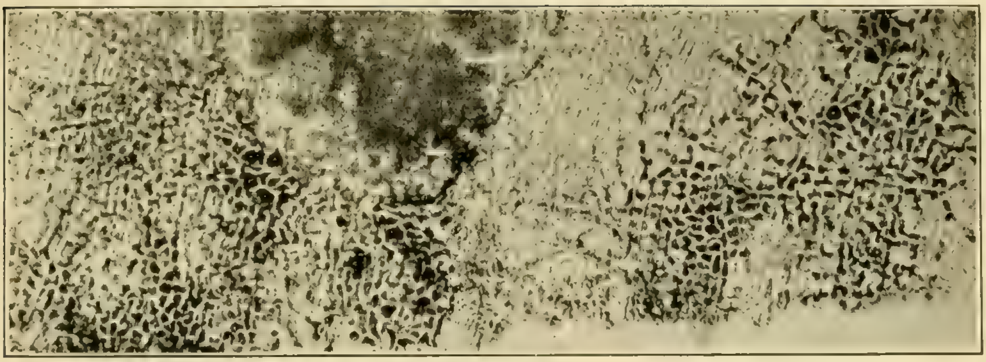

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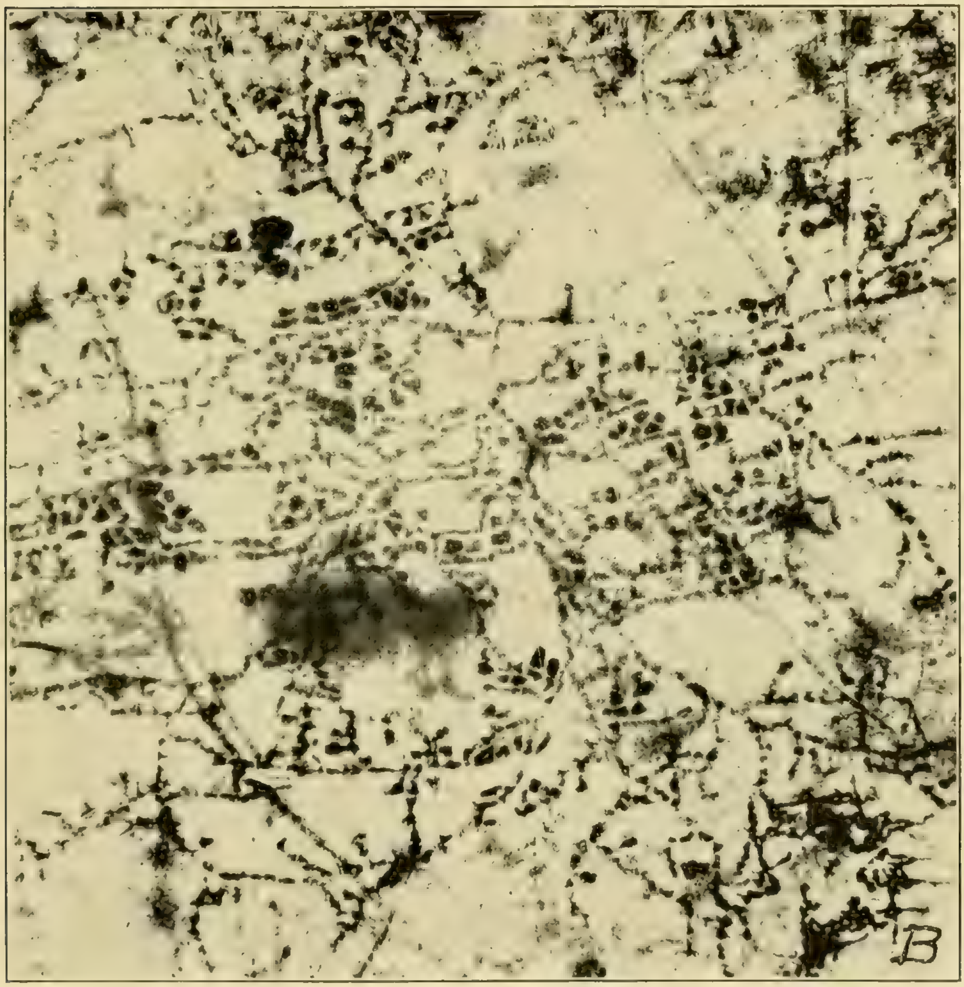

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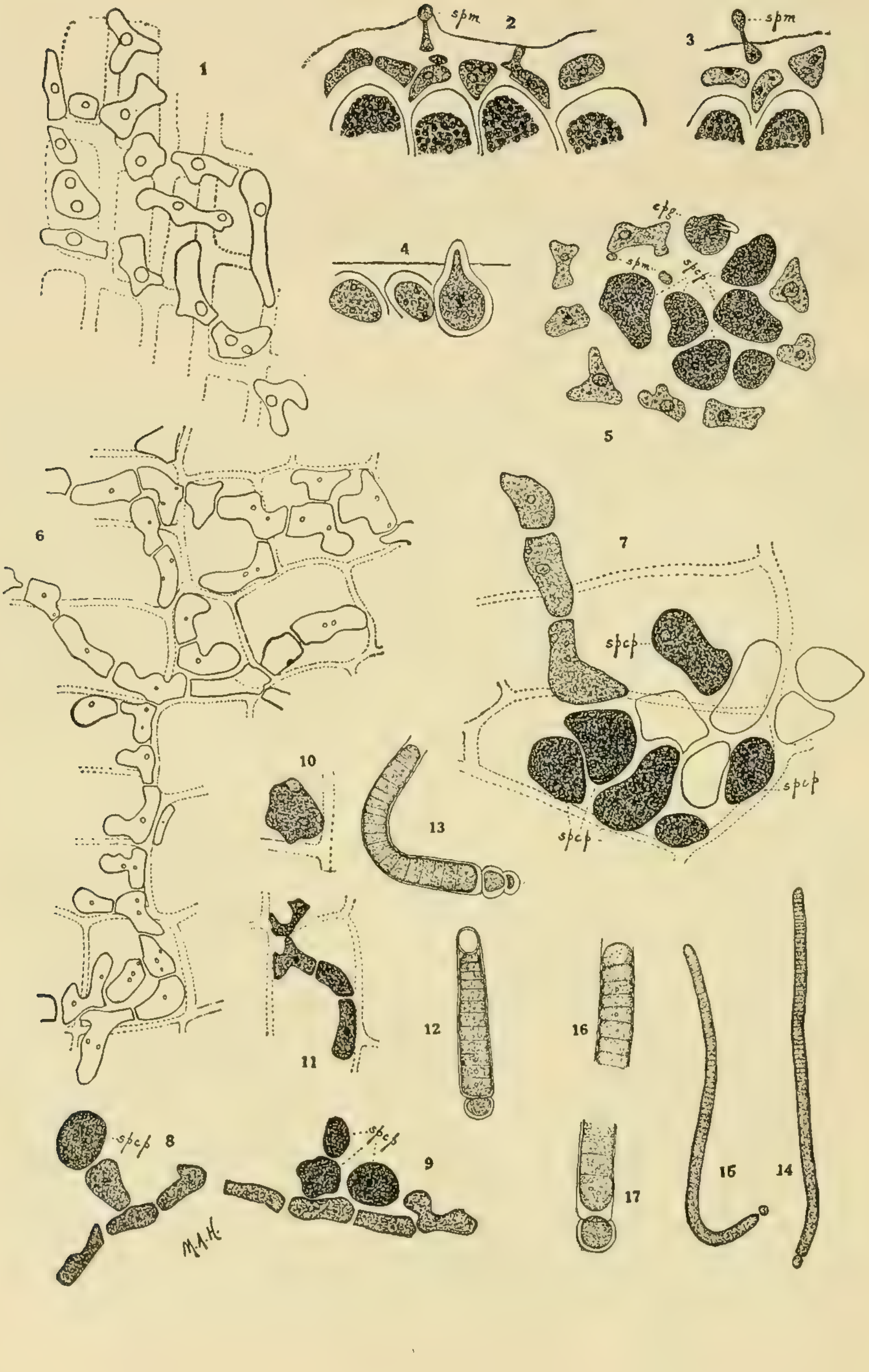
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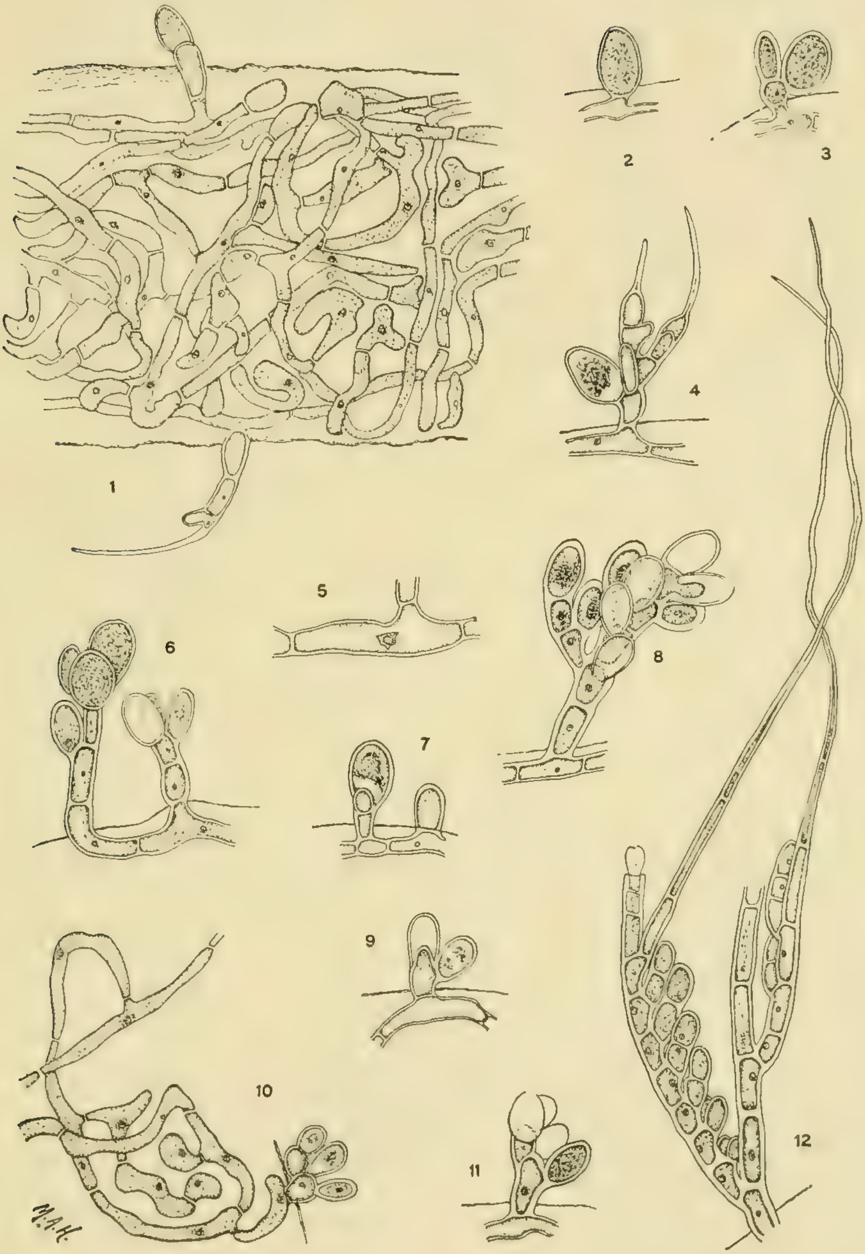
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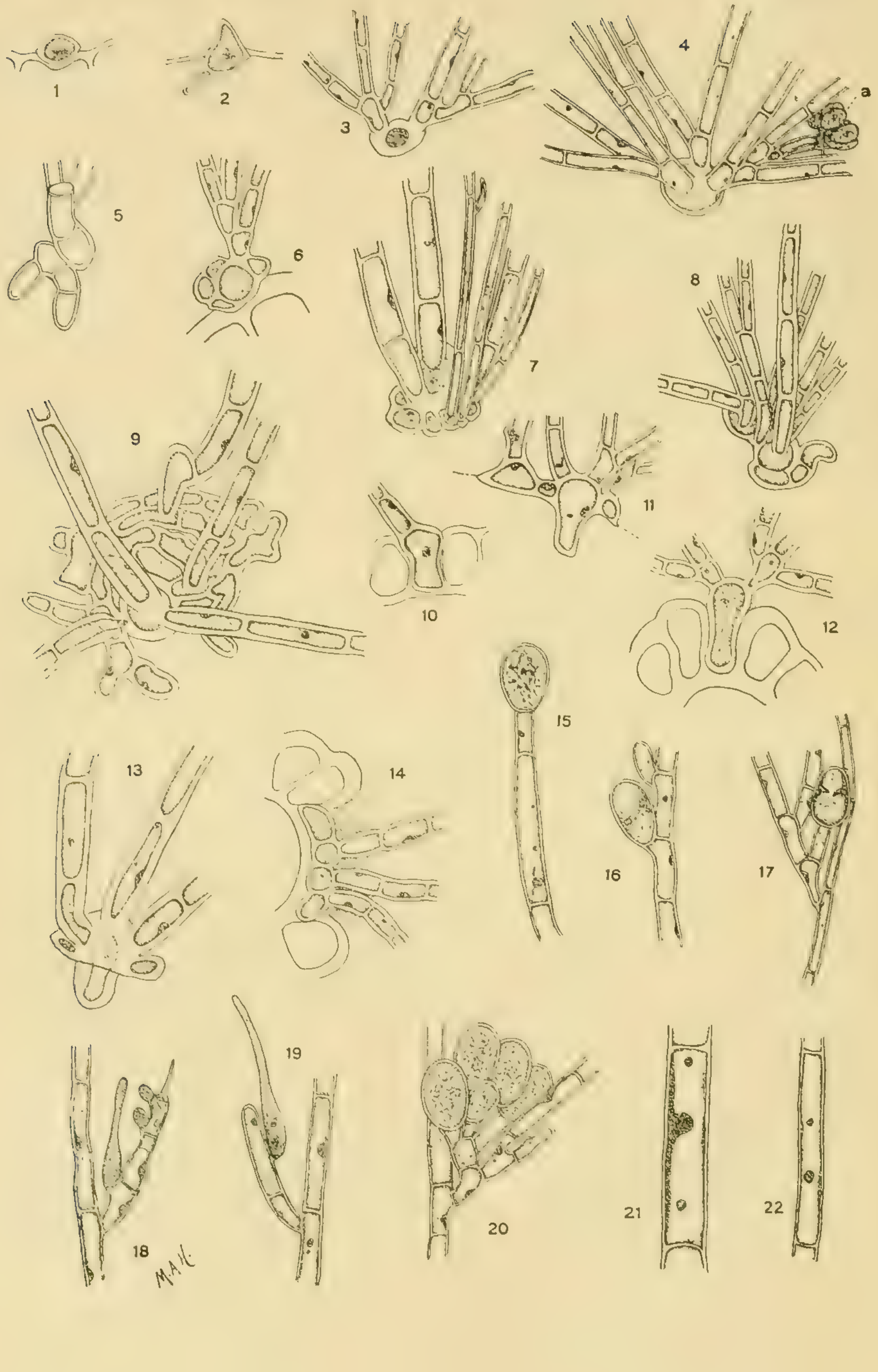
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